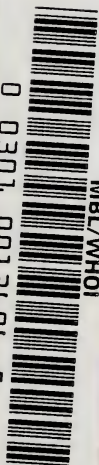






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# THE BOTANY OF ICELAND

EDITED

BY

L. KOLDERUP ROSENVINGE

PH. D.

AND

EUG. WARMING

PH. D., SC. D.

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**VOL. I**

WITH ONE PLATE AND 82 FIGURES IN THE TEXT



COPENHAGEN  
J. FRIMODT

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LONDON  
JOHN WHELDON & CO.  
1912-1918

PUBLISHED BY THE AID OF THE CARLSBERG FUND

## CONTENTS

	Page
PART I.	
PREFACE.....	III
1. HELGI JÓNSSON: The Marine Algal Vegetation of Iceland. 1912	1
2. TH. THORODDSEN: An Account of the physical Geography of Iceland. 1914.....	187
PART II. 1918.	
3. ERNST ØSTRUP: Marine Diatoms from the Coasts of Iceland (with one Plate). (Printed in 1916) .....	345
4. AUG. HESSELBO: The Bryophyta of Iceland.....	395

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## PART I

1. THE MARINE ALGAL VEGETATION BY HELGI JÓNSSON, PH. D.

(PUBLISHED BY THE AID OF THE CARLSBERG FUND)



COPENHAGEN

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## PREFACE.

IT was mentioned in the preface to the "Botany of the Færøes" (Copenhagen & London, 1901—1908) that, on the completion of that work, Iceland would be the one island among the dependencies of the Danish kingdom in the Atlantic which was in most need of a thorough and systematic investigation as regards its botany, and the hope was expressed that this would be commenced as early as the year 1909. This hope has been so far realized that we, the undersigned, are now able to publish the first paper on the subject, viz. "The Marine Algal Vegetation" by Dr. HELGI JÓNSSON of Reykjavík.\* Iceland, however, is so large compared with the Færøes that the investigation will not only be far more difficult to carry out, but will also extend over a far longer period.

We hope that specialists in botany may be able, at short intervals, to visit the island and make collections and notes. Thus, even in 1910 a young bryologist, A. HESSELBO, studied the moss-vegetation — when he took the photographs, published in the present paper — and this summer he is again paying a visit to the island, after which he will prepare an account of the moss-flora and the moss-vegetation of Iceland.

Next summer we hope that a young lichenologist will be able to set to work in a similar manner, and will be followed by others, until the work can be completed with a general account of the vegetation and the plant-geographical position of the island.

L. KOLDERUP ROSENVINGE.

EUG. WARMING.

COPENHAGEN, AUG. 1912.





1.

THE MARINE ALGAL VEGETATION  
OF ICELAND

BY

HELGI JÓNSSON

PH. D.

WITH 7 FIGURES IN THE TEXT



# CONTENTS.

	Page
Introduction .....	1
I List of the Marine Algæ .....	5
II Life-conditions of the Marine Algal Vegetation.....	25
1. The Nature of the coast .....	25
2. The Ocean .....	27
A. The Movements of the Ocean .....	27
B. The Temperature of the Water .....	32
C. The Salinity .....	40
3. The Air.....	42
A. The Temperature.....	42
B. The Humidity.....	44
C. Precipitation, Amount of Cloud, Foggy days, Wet days.....	44
D. Winds .....	46
4. The Light .....	47
III The Horizontal Distribution of the Species and the Components of the Algal Flora .....	48
The Components of the Algal Flora .....	58
A. The Arctic Group .....	58
B. The Subarctic Group .....	59
C. The Boreal-Arctic Group.....	60
D. The Cold-Boreal Group .....	61
E. The Warm-Boreal Group....	62
Floristic Boundaries .....	66
IV Comparison with neighbouring Floral Districts .....	68
V The Vertical Distribution of the Species.....	80
A. Upper Littoral Zone.....	85
B. The lower Littoral Zone and the Belt below down to a depth of about 10 metres .....	88
C. The Sublittoral Species .....	91
Lower Limits of Growth .....	92

	Page
VI Marine Algal Vegetation and Sea-grass Vegetation .....	95
Account of the Marine Algal Vegetation and the Sea-grass Vegetation ...	98
A. The Marine Algal Vegetation .....	99
a. The Littoral Zone .....	99
aa. The Photophilous or strictly Littoral Communities .....	99
1. The <i>Prasiola stipitata</i> -association .....	100
2. The Community of Filiform Algæ .....	102
3. The Community of Fucaceæ .....	106
4. The Enteromorpha-association .....	120
5. The <i>Acrosiphonia</i> -association .....	121
bb. The Shade-vegetation .....	123
6. The <i>Hildenbrandia</i> -association .....	123
7. The <i>Rhodochorton</i> -association, the <i>Sphacelarietum bri-</i> <i>tannici</i> and the <i>Polysiphonietum urceolatæ</i> .....	123
cc. The Vegetation of Tide-Pools .....	125
b. The Semi-littoral Zone .....	128
8. The <i>Monostroma</i> -association .....	129
9. The <i>Chorda</i> -association .....	130
10. The Community of <i>Rhodymenia</i> .....	132
11. The <i>Polysiphonia urceolata</i> -association .....	133
12. The Community of <i>Corallina</i> .....	135
13. The Crustaceous alga-association .....	138
c. The Sublittoral Zone .....	139
14. The Community of <i>Laminariaceæ</i> .....	140
15. The <i>Desmarestia</i> -association .....	151
16. The Deep-water Community of <i>Florideæ</i> .....	152
17. The <i>Lithothamnion</i> -association .....	154
18. The Community of Crustaceous Algæ .....	155
B. The Sea-grass Vegetation .....	157
The <i>Zostera</i> -association .....	157
VII Differences in the Vegetation in East and South Iceland .....	159
VIII Some Notes on the Biology of the Algæ along the coast of Iceland .....	166
1. Duration of Life .....	166
2. Periodical Changes .....	169
3. Littoral Winter-vegetation of Reykjavík .....	180
Bibliography .....	183





## INTRODUCTION.

IT is far from being a fact that the Marine Algal Flora and Marine Algal Vegetation of Iceland can be regarded as sufficiently known; this does not apply in the same degree, however, to all parts of the coast. East Iceland, South Iceland and South-west Iceland are better known in this respect than North-west Iceland and North Iceland. Also, as is very natural, the littoral vegetation is better known than the sublittoral, as it is easier of access and may be investigated directly on the spot, while, as regards the sublittoral vegetation, one has to be content with what is obtained from dredgings.

Very little has previously been written with regard to the marine algal vegetation of Iceland. Strömfelt, who travelled in Iceland in the summer of 1883, has treated the algal flora exhaustively (see Jónsson, 31) in his valuable work "Om Algevegetationen vid Islands kuster" (70) and has given a critical review of the older literature of the marine algal flora of Iceland; but, on the other hand, he has dealt very briefly with the marine algal vegetation. He follows Kjellman in dividing the vegetation in question into a littoral and a sublittoral vegetation. Strömfelt found the littoral vegetation poorly developed in many places — he records, however, a luxuriant littoral vegetation from Reykjavík, Eyrarbakki and Eskifjörður. The sublittoral vegetation is mentioned even more briefly, and is emphasized as being more uniform than the littoral as regards its distribution and the species which compose it. Strömfelt does not make any definite statement regarding the elittoral vegetation, owing to his not having dredged in sufficiently deep water, but he considers it improbable that any vegetation worthy of notice occurs at that depth, as he did not find any rich vegetation at a greater depth than 10—12 fathoms.

The reason why Strömfelt found the littoral vegetation on the north coast so poorly developed may be two-fold: it may result

from the drift-ice having remained at the coast during the whole summer of the previous year (1882), but it may also be due to the fact that, in this case, Strömfelt went by steamer from port to port, and could scarcely have obtained a thorough knowledge of the coast in as much as the steamer usually stops only a short time at each port.

Strömfelt mentions the following algal formations: the *Fucaceæ*-formation which is reported from Hólmanes and Seley in E. Iceland; the *Laminaria*-formation, under which a subvegetation of red algæ is mentioned. Further, a *Monostroma*-vegetation is recorded as occurring near Ekifjörður at a depth of two fathoms on a sandy bottom, and a *Halosaccion*-formation at extreme low-water mark on Hólmanes. Strömfelt expresses the opinion, moreover, that a *Corallina*-formation formed by *Lithothamnion*-species must exist, but he does not say anything definite regarding this point, as he received almost all the *Lithothamnion*-species from the fishermen (70, pp. 10, 11). The description of the vegetation is evidently based on observations made in places where Strömfelt stayed for a longer time, viz. Eskifjörður and Reyðarfjörður in E. Iceland, and Eyrarbakki in S. Iceland. I have incorporated Strömfelt's observations with my own in my description of the vegetation.

Strömfelt, on the other hand, treats exhaustively of the distribution of the species along the coasts. Thus he is the first to substantiate the existence of two floral districts in the sea on the coasts of Iceland: a cold-water flora in NE. Iceland and a warm-water flora in SW. Iceland. In a table he gives a summary of the distribution of the species along the coast of Iceland, and states whether they are found in the Norwegian Polar Sea, the North Atlantic and the Greenland Sea. He records 33 species as common to NE. Iceland and SW. Iceland, 33 species as growing in NE. Iceland and absent from SW. Iceland, and 28 species as growing in the latter district and absent from the former. Thus 66 species in all are recorded from NE. Iceland and 61 species from SW. Iceland. Of the species given by Strömfelt as being found in or absent from NE. Iceland and SW. Iceland respectively, later investigations have proved that far the greater number are common to both places, but then, again, other species have been found which are characteristic of the different districts.

My description of the algal vegetation along the coast of Iceland is based mainly on my own observations, and further on

Strömfelt's work, as well as on Ostenfeld's observations. The latter mainly concern the littoral zone, and originate from E. Iceland (Hólmanes), SW. Iceland (Reykjavík, Njarðvík) and S. Iceland (Staður on the south side of Reykjanes).

Ostenfeld, moreover, has given information of the sublittoral vegetation of Myrakollur in NW. Iceland.

My own observations are drawn from various places encircling the whole of Iceland. In E. Iceland I have especially investigated Berufjörður, Reyðarfjörður and Seyðisfjörður, and everything which is narrated of the algal vegetation from E. Iceland originates from these fjords. In N. Iceland I have examined Eyjafjörður fairly accurately, from its innermost part to the submarine ridge off Hrísey, and I have, moreover, in the course of my journey, investigated the head of Húnaflói. When travelling by the mail steamer "Laura" round NW. Iceland I visited all the fjords from Skutulsfjörður to Patreksfjörður. I stayed only a short time in each fjord, as I accompanied the boat from port to port, and was only able to dredge and investigate the littoral zone in the vicinity of the towns. In SW. Iceland I have been at the south side of Breiðifjörður, and have dredged along the stretch of coast from Röst in Hvammsfjörður to Hjallasandur, and have also examined the littoral zone over a far larger area, not only round Snæfellsnes but also in Dalasysla. Round Reykjavík I have dredged and investigated the littoral zone many times. In S. Iceland I have investigated the Vestmannaeyjar most thoroughly and have, in addition, dredged and examined the littoral zone at Eyrarbakki. All remarks concerning the algal vegetation of S. Iceland are based on observations drawn from the western part of the south coast. The eastern part of the south coast from about Stokkseyri eastward is, as far as I know, a sandy coast, a "desert" devoid of algal vegetation. I have not dredged further east than round the Vestmannaeyjar, but on my trip through S. Iceland in 1901 I saw very few algæ cast ashore, which may be regarded as a sure sign that a desert lies beyond, because, where algal vegetation exists, it is quite common, with a landward wind, for large, often astonishingly large quantities of algæ to be thrown up on the shore. What might not be found then, on the south coast, where the swell of the Atlantic rolls up onto the flat shore, if any algal vegetation existed further out! Nor can it be expected that anything but a desert exists off this coast, as the bottom consists of sand, and the coast lies exposed to the sea, like the west coast of Jutland. Where, on the other hand, there

are rocks, there vegetation is sure to occur. At Vík in Myrdal near the southern point of Iceland there was, for instance, a poor vegetation on the rocks.

When one considers how great is the extent of Iceland's coastline, one cannot expect this to be sufficiently elucidated as regards the distribution of marine algæ by the few and scattered investigations which have been undertaken. For a long time, then, I nourished the hope of being able to undertake further investigations, and therefore constantly deferred publishing a comprehensive description of the algal vegetation. Now, however, I have decided to delay no longer and hope in the future to be able to make a more extensive contribution in several respects towards the elucidation of the algal vegetation.

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## I. LIST OF THE MARINE ALGÆ.

THE following List of the Marine Algæ of Iceland is extracted from my earlier publications (Jónsson, 31, Börgesen and Jónsson, 14) and from the paper by Henning Petersen (57) on the species of *Ceramium*. It gives only the names of the species with synonyms, their distribution in the different coastal districts and some new habitats. The limitation of species is unchanged except in the case of the genus *Ceramium* and in *Clathromorphum circumscriptum* (Strömf.) which is included in *Clathromorphum compactum* (Kjellm.) as proposed by Foslie. One species, *Vaucheria sphærospora* Nordst. (Börgesen and Jónsson, 14), is omitted from the list as it can scarcely be called a Marine Alga. Of *Ceramium* 5 species are added.

Thus the number of species is: —

76 Rhodophyceæ

67 Phæophyceæ

51 Chlorophyceæ

6 Cyanophyceæ

---

Total... 200 species.

The coastal districts are the following (see the map, p. 7): —  
East Iceland (E. Icel.), from Lónsheiði (Eystra horn) to Langanes.  
North Iceland (N. Icel.), from Langanes to Hornbjarg (Kap Nord).  
Northwest Iceland (NW. Icel.), from Hornbjarg to Látrabjarg.  
Southwest Iceland (SW. Icel.), Breiðifjörður and Faxaflói from Látrabjarg to Reykjanes.  
South Iceland (S. Icel.) from Reykjanes to Vestmannaeyjar and eastwards to Lónsheiði (Eystra horn).

In "The Marine Algæ of Iceland" (Jónsson, 31) the district NW. Icel. is larger; it reaches from the inner end of Húnaflói to Látrabjarg instead of as now from Hornbjarg to Látrabjarg. Localities from the part of the coast which stretches from Húnaflói to Horn-

bjarg are referred to NW. Icel., in the paper mentioned above, but in the present work (cf. Jónsson, 33, p. 11) to North Iceland. These localities are: Hrútafjörður, Prestsbakki, Kolbeinsá, Skálholtsvík, Kollafjarðarnes, Broddanes and Grímsey in Húnaflói.

## RHODOPHYCEÆ.

### BANGIOIDEÆ.

#### Fam. **Bangiaceæ.**

**Bangia fuscopurpurea** (Dillw.) Lyngb., K. Rosenv., 61, p. 831.

E. Icel., N. Icel., SW. Icel., S. Icel.

**Porphyra umbilicalis** (L.) J. Ag., K. Rosenv., 61, p. 830; *P. laciniata* Strömf., 70, p. 34.

Common in all parts of the coast of Iceland.

**Porphyra miniata** (Ag.) Ag., K. Rosenv., 61, p. 826; *Diploderma* m., *D. tenuissimum*, *D. amplissimum* Strömf., 70, p. 33.

Found in all parts of the coast.

**Porphyropsis coccinea** (J. Ag.) K. Rosenv., 65, p. 69; *Porphyra coccinea* Jónsson, 31.

SW. Icel.: Reykjavík, S. Icel.

**Conchocelis rosea** Batters.

Found in all parts of the coast.

### FLORIDEÆ.

#### Fam. **Helminthocladiaceæ.**

**Chantransia virgatula** (Harv.) Thur., K. Rosenv., 61, p. 824.

NW. Icel., SW. Icel.

**Chantransia secundata** (Lyngb.) Thur., K. Rosenv., 61, p. 824.

Found in all parts of the coast.

**Chantransia Alariæ** H. Jónsson, 31.

SW. Icel., S. Icel.: Eyrarbakki.

**Chantransia microscopica** (Naeg.) Fosl. On *Cladophora gracilis* in the littoral zone. Thallus has long hairs. Published in Börgesen and Jónsson, 14.

N. Icel.: Kolbeinsá.

The specimens mentioned under this name belong most probably to another species of *Chantransia* with a unicellular base.

Fam. **Gigartinaceæ.**

**Chondrus crispus** (L.) Stackh., Strömf., 70, p. 31.

NW. Icel. (cast ashore), SW. Icel., S. Icel.

**Gigartina mamillosa** (Good. et Wood.) J. Ag., Strömf., 70, p. 31.

Found in all parts of the coast, common in SW. Icel. and S. Icel.

**Ahnfeltia plicata** (Huds.) Fries, Strömf., 70, p. 31.

Cast ashore on N. Icel. and NW. Icel., common in SW. Icel. and S. Icel.



Fig. 1.

**Phyllophora Brodiai** (Turn.) J. Ag. *\*interrupta* (Grev.) K. Rosenv., 61, p. 821.

E. Icel., NW. Icel.

**Phyllophora membranifolia** (Good. et Wood.) J. Ag., Strömf., 70, p. 30.

SW. Icel., S. Icel.

**Actinococcus subcutaneus** (Lyngb.) K. Rosenv., 61, p. 822.

E. Icel., NW. Icel.

**Ceratocolax Hartzii** K. Rosenv., 62, p. 34.

NW. Icel.

Fam. **Rhodophyllidaceæ.**

**Cystoclonium purpurascens** (Huds.) Kütz., Strömf., 70, p. 30.

N. Icel., NW. Icel. (cast ashore), common in SW. Icel. and S. Icel.

**Turnerella Pennyi** (Harv.) Schmitz, K. Rosenv., 62, p. 29.  
E. Icel., N. Icel.

**Euthora cristata** (L.) J. Ag., Strömf., 70, p. 27.  
Common around the coast of Iceland.

**Rhodophyllis dichotoma** (Lepech.) Gobi, Strömf., 70, p. 26.  
Common around the coast of Iceland.

### Fam. **Rhodymeniaceæ.**

**Rhodymenia palmata** (L.) Grev., Kjellman, 36, p. 147; Strömfelt, 70, p. 27; *R. pertusa* Strömf., 70, p. 28.  
Very common around the coast of Iceland.

**Lomentaria clavellosa** (Turn.) Gaill.; Le Jol., Liste des Algues mar. de Cherb., p. 132, var. *sedifolia* Ag.  
S. Icel.

**Lomentaria rosea** (Harv.) Thur., Le Jol., Liste des Alg. mar. de Cherb., p. 131, Fig. Harv. Phyc. Brit., T. 358 and 301.  
S. Icel.

**Plocamium coccineum** (Huds.) Lyngb., Strömf., 70, p. 27.  
S. Icel.

**Halosaccion ramentaceum** (L.) J. Ag., Kjellm., 36, p. 153; Strömf., 70, p. 29; *H. scopula* Strömf., 70.  
Common around the coast of Iceland.

### Fam. **Delesseriaceæ.**

**Delesseria alata** (Huds.) Lam., Strömf., 70, p. 24.  
SW. Icel., S. Icel.

**Delesseria Baerii** (Post. et Rupr.) J. Ag.; *\*corymbosa* (J. Ag.) K. Rosenv., 61, p. 806.

There is a specimen of this plant in the herbarium of the Botanical Museum in Copenhagen; it is labelled "Islandia d. Möreck."

**Delesseria sinuosa** (Good. et Wood.) Lam., Strömf., 70, p. 24.  
Common around Iceland.

**Delesseria sanguinea** (L.) Lam.; *Hydrolapathum* s. Strömf., 70, p. 26.  
E. Icel.; rather common in SW. Icel. and S. Icel.

### Fam. **Bonnemaisoniaceæ.**

**Bonnemaisonia asparagoides** (Wood.) C. Ag.

In the herbarium of the Botanical Museum in Copenhagen there are three specimens of this species, said to have been collected in Ice-

land. On one of the labels is written "misit Faber." In Flora Danica T. 2579 a specimen of this plant is figured, regarding which Liebmann writes: "ad littora Islandiæ pr. Reykjavik legit beatus Faber, cujus specimina mecum communicavit cl. Hofman-Bang."

### Fam. **Rhodomelaceæ.**

**Pterosiphonia parasitica** (Huds.) Falkenberg, Die Rhodomelaceen des Golfes von Neapel. *Polysiphonia* p. Kjellman, 36, p. 117; H. Jónsson, 31, p. 142.

S. Icel.

**Polysiphonia urceolata** (Lightf.) Grev., Strömf., 70, p. 24.

Common around Iceland.

**Polysiphonia fastigiata** (Roth) Grev., Strömf., 70, p. 24.

NW. Iceland.; common in SW. Icel. and S. Icel.

**Polysiphonia arctica** J. Ag., K. Rosenv., 61, p. 800.

E. Icel., N. Icel. and NW. Icel. common; SW. Icel.

**Polysiphonia nigrescens** (Huds.) Harv., Kjellman, 36, p. 126.

N. Icel., SW. Icel.

**Rhodomela lycopodioides** (L.) Ag., Strömf., 70, p. 23.

Common around Iceland.

**Odonthalia dentata** (L.) Lyngb., Strömf., 70, p. 23.

Common around Iceland.

### Fam. **Ceramiceæ.**

**Callithamnion Arbuscula** (Dillw.) Lyngb., Strömf., 70, p. 32.

Rather common in SW. Icel. and S. Icel.

**Callithamnion scopulorum** C. Ag., Spec. Alg. (2), p. 176.

SW. Icel., S. Icel.

**Plumaria elegans** (Bonnem.) Schmitz, Syst. Uebersicht der bisher bekannten Gattungen der Florideen, Flora oder allgem. bot. Zeit., 1889; *Ptilota* e. Kjellman, 36, p. 172.

SW. Icel., S. Icel.

**Ptilota plumosa** (L.) Ag., Strömf., 70, p. 32.

N. Icel.; common in NW. Icel., SW. Icel. and S. Icel.

**Ptilota pectinata** (Gunn.) Kjellm., Strömf., 70, p. 32.

Common in E. Icel., N. Icel. and NW. Icel.; rather rare in SW. Icel.

**Antithamnion Plumula** (Ellis) Thur.  $\beta$  *boreale* Gobi, K. Rosenv., 61, p. 787. *A. boreale* Strömf., 70, p. 32.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Antithamnion floccosum** (Müll.) Kleen, Strömf., 70, p. 32.

E. Icel., SW. Icel., S. Icel.

**Ceramium acanthonotum** Carm., Kjellm., 36, p. 171.

SW. Icel., S. Icel.

**Ceramium Deslongchampsii** Chauv., Petersen, 57, p. 108; **Ceramium rubrum** ex pte. Jónsson, 31.

SW. Icel.: Reykjavík (L. Kolderup Rosenvinge, <sup>5</sup>/<sub>6</sub> 1886).

**Ceramium fruticulosum** Kütz., Petersen, 57, p. 108.

SW. Icel.: Seltjarnarnes (Helgi Jónsson, <sup>28</sup>/<sub>8</sub> 1907).

**Ceramium circinnatum** Ag., Petersen, 57, p. 111; **Ceramium rubrum** ex pte. Jónsson, 31.

SW. Icel.: Stykkishólmur (Hèlgi Jónsson, <sup>16</sup>/<sub>6</sub> 1897), Skerjafjörður (Helgi Jónsson, <sup>10</sup>/<sub>7</sub> 1905).

**Ceramium arborescens** J. Agardh, Petersen, 57, p. 112; **Ceramium rubrum** ex pte. Jónsson, 31.

N. Icel.: Hrísey (Helgi Jónsson, <sup>2</sup>/<sub>7</sub> 1898); NW. Icel.: Látravík in Aðalvík (C. H. Ostenfeld, <sup>8</sup>/<sub>7</sub> 1896); SW. Icel.: Reykjavík (L. Kolderup Rosenvinge, <sup>5</sup>/<sub>6</sub> 1886).

**Ceramium atlanticum** Petersen, 57, p. 112; **Ceramium rubrum** ex pte. Jónsson, 31.

SW. Icel.: Gróttá (Helgi Jónsson, <sup>17</sup>/<sub>6</sub> 1908), Hafnarfjörður (Hjalmar Jensen, <sup>7</sup>/<sub>5</sub> 1890); S. Icel.: Staður (C. H. Ostenfeld, <sup>12</sup>/<sub>6</sub> 1896), Eyrarbakki (Helgi Jónsson, <sup>31</sup>/<sub>5</sub> 1897), Vestmannaeyjar (Helgi Jónsson, <sup>14</sup>/<sub>5</sub> 1897).

**Ceramium rubrum** (Huds.) Agardh, Petersen, 57, p. 113; Jónsson, 31, ex pte.

N. Icel., NW. Icel., SW. Icel., S. Icel.

**Rhodochorton Rothii** (Turt.) Naeg., K. Rosenv., 61, p. 791.

E. Icel., N. Icel., NW. Icel., SW. Icel. (common), S. Icel.

**Rhodochorton repens** H. Jónsson, 31.

S. Icel.

**Rhodochorton minutum** Suhr. Descr. in Reinke's Atlas (59), Fig. Reinke's Atlas T. 40.

SW. Icel.

**Rhodochorton penicilliforme** (Kjellm.) K. Rosenv., Les Algues marines du Groenland in Ann. Sc. nat., 7<sup>e</sup> Sér., XIX.

E. Icel., N. Icel., NW. Icel., SW. Icel.



**Rhodochorton membranaceum** Magnus, K. Rosenv., 61, p. 794; P. Kuckuck, Beiträge zur Kenntniss der Meeresalgen, 1897.

E. Icel., N. Icel., NW. Icel., SW. Icel.

Fam. **Dumontiaceæ.**

**Dumontia filiformis** (Fl. Dan.) Grev., Strömf., 70, p. 30.

E. Icel., SW. Icel. (rather common), S. Icel.

**Dilsea edulis** Stackh., Sarcophyllis edulis Kjellm., 36, p. 152.

SW. Icel.

Fam. **Squamariaceæ.**

**Petrocelis Hennedyi** (Harv.) Batters, A list of the Marine Algæ of Berwick-on-Tweed.

N. Icel.: Hraunakrókur (O. Davíðsson), NW. Icel., SW. Icel., S. Icel.

**Cruoria arctica** Schmitz, K. Rosenv., 61, p. 784.

SW. Icel.

**Cruoria pellita** (Lyngb.) Fries, Kjellm., 36, p. 142.

SW. Icel., S. Icel.: Eyrarbakki.

**Peyssonellia Rosenvingii** Schmitz, K. Rosenv., 61, p. 782; Hæmatostagon balanicola Strömf., 70, p. 25?

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Rhododermis parasitica** Batters, A list of the Marine Algæ of Berwick-on-Tweed.

NW. Icel., SW. Icel., S. Icel.

Fam. **Corallinaceæ.**

**Lithothamnion glaciale** Kjellm., Strömf., 70, p. 18.

E. Icel., N. Icel., SW. Icel.

**Lithothamnion Unger** Kjellm., 36, p. 91 excl. syn.; L. intermedium Strömf., 70, p. 19.

E. Icel., N. Icel., NW. Icel.

**Lithothamnion tophiforme** Unger, Foslie, The Norwegian forms of Lithothamnion, 1895, p. 119; L. soriferum Strömf., 70, p. 18.

E. Icel., N. Icel., SW. Icel.: Hvalfjörður (Hörring), S. Icel.

**Lithothamnion flavescens** Kjellm., 36, p. 98.

E. Icel.

**Lithothamnion foecundum** Kjellm., 36, p. 99.

E. Icel., N. Icel.

**Lithothamnion læve** (Strömf.) Foslie, List of species of the Lithothamnion p. 7; Lithophyllum læve Strömf., 70, p. 21.

E. Icel., N. Icel., NW. Icel., SW. Icel., S. Icel.

**Lithothamnion Lenormandi** (Aresch.) Foslie, The Norwegian forms of Lithothamnion, 1895, p. 150.

SW. Icel.

**Phymatolithon polymorphum** (L.) Foslie, List of species of the Lithothamnion p. 8; Lithothamnion polymorphum Strömf., 70, p. 19.

S. Icel.

**Clathromorphum compactum** (Kjellm.) Foslie, Lithothamnion compactum Kjellm., 36, p. 101; *Clathromorphum circumscriptum* (Strömf.) Fosl., Lithothamnion circumscriptum Strömf., 70, p. 20.

In all parts of the coast.

**Lithophyllum Crouani** Fosl., List of species of the Lithothamnion, p. 10.

N. Icel., NW. Icel., S. Icel.: Eyrarbakki.

**Dermatolithon macrocarpum** (Ros.) Fosl., Revised systematical survey of the Melobesieæ, p. 21; Melobesia macrocarpa Strömf., 70, p. 23.

SW. Icel., S. Icel.

**Corallina officinalis** L., Strömf., 70, p. 18.

N. Icel., NW. Icel., SW. Icel., S. Icel.

**Hildenbrandia rosea** Kütz, Strömf., 70, p. 24.

Common around the coast of Iceland.

## PHÆOPHYCEÆ.

### Fam. Myrionemaceæ.

**Lithoderma fatiscens** Aresch., emend. Kuck., Bemerk. I (47), p. 238.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Petroderma maculiforme** (Wollny) Kuck., Bemerk. II (47), p. 382.

N. Icel.

**Ralfsia ovata** K. Rosenv., 61, p. 900; 62, p. 94.

N. Icel.: Húsavík (Ove Paulsen), Prestsbakki; SW. Icel.

**Ralfsia clavata** (Carm.) Farl., Mar. Alg., p. 88; Reinke (59) Atlas T. 5 and 6, figs. 14—20; *Stragularia adhærens* Strömf., 70, p. 49, T. II, figs. 13—15.

E. Icel., N. Icel., NW. Icel., SW. Icel.



**Ralfsia verrucosa** (Aresch.) J. Ag., Reinke (59), Atlas T. 5 and 6, figs. 1—13.

E. Icel., N. Icel., SW. Icel.

**Ralfsia deusta** (Ag.) J. Ag., K. Rosenv., 61, p. 898.

E. Icel., N. Icel., SW. Icel., S. Icel.

**Myrionema vulgare** Thuret, Sauvageau, 66, p. 185.

N. Icel., SW. Icel.

**Myrionema Corunnæ** Sauvag., 66, p. 237.

S. Icel.

**Myrionema globosum** (Rke) Fosl., New or critical Norw. Algæ, p. 17; *Ascocyclus globosus* Rke, 58, p. 46; Atlas (59) T. 17; *Phycocelis globosus* K. Rosenv., 62, p. 86, figs. 19—20.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Myrionema færøense** Börge., 13, p. 424.

SW. Icel.

**Myrionema Laminariæ** (K. Rosenv.), *Dermatocelis Laminariæ* K. Rosenv., 62, p. 89, fig. 21.

SW. Icel.

**Ascocyclus islandicus** H. Jónsson, 31, p. 149.

N. Icel.

Probably this species will prove to be identical with *A. sphærophorus* Sauv., cf. Jónsson, 31, p. 151 and Kylin.<sup>1</sup> The last-named author writes that *A. islandicus* without doubt is identical with *A. sphærophorus*, but he gives no particulars as to the chromatophores of the last-named species, I therefore must still regard the Icelandic plant as a distinct species.

### Fam. **Ectocarpaceæ.**

**Microsyphar Polysiphoniæ** Kuck., Beiträge (48) p. 29.

NW. Icel., SW. Icel.

**Streblonema æcidioides** K. Rosenv., 61, p. 894; 62, p. 80; *Phycocelis æcidioides* Kuck., Bemerk. I (57), p. 234.

E. Icel., N. Icel., SW. Icel.

**Streblonema Stilophoræ** Cr. var. *cæspitosa* K. Rosenv., 61, p. 892.

Found in all parts of the coast.

**Pylaiella littoralis** (L.) Kjellm.; *Ectocarpus littoralis*, Kuck., 48, p. 7; Rosenv., 61, p. 881; *Pylaiella littoralis*, *Pylaiella varia* Kjellm., 35, p. 83.

Common around the coast of Iceland.

<sup>1</sup> Harald Kylin, Zur Kenntnis der Algenflora der Norwegischen Westküste, Arkiv för Botanik, Bd. 10, No. 1, 1910.

**Ectocarpus tomentosoides** Farl., New or imperfectly known Algæ of U. S., reprint from Bull. Torr. Bot. Club, Vol. XVI, 1889, p. 11, T. 87, fig. 4; K. Rosenv., 61, p. 180; Gran, En norsk form af Ectoc. tomentosoides Farl., Christiania Vidensk. Selsk. Forhandl. for 1883, No. 17; Kuckuck, Ueber Polymorphie bei einigen Phæosporeen in Festschrift für Schwendener, p. 370, figs. 5—7.

E. Icel., N. Icel., NW. Icel.; common in SW Icel. and S. Icel.

**Ectocarpus tomentosus** (Huds.) Lyngb., Hydr. Dan. (51) p. 132; Kjellman, 35, p. 73.

SW. Icel., S. Icel.

**Ectocarpus confervoides** (Roth) Le Jol., Kuck., 48, p. 19; Kjellman, 35, p. 77, ex pte.; K. Rosenv., 61, p. 883, ex pte.

Found in all parts of the coast.

**Ectocarpus siliculosus** (Huds.) Lyngb., Hydr. Dan. (51) p. 131; Kjellman, 35, p. 78; Kuck. 48, p. 15.

N. Icel., SW. Icel.

**Ectocarpus penicillatus** (Ag.) Kjellm., 35, p. 76; E. confervoides f. penicillata Kjellman, 39, p. 79.

E. Icel., N. Icel., SW. Icel.

**Ectocarpus fasciculatus** (Griff.) Harv., Kjellm. 35, p. 76.

SW. Icel., S. Icel.

**Ectocarpus Hinksiaë** Harv., Manual, p. 59; Phyc. Brit., T. 22; Sauvageau, Observations relatives à la sexualité des Phéosporées (Journal de Botanique, 1896).

S. Icel.

### Fam. **Elachistaceæ.**

**Leptonema fasciculatum** Rke, 58, p. 50; var. subcylindrica K. Rosenv., 61, p. 879.

N. Icel., NW. Icel., SW. Icel.

**Elachista fucicola** (Vell.) Aresch., emend. K. Rosenv., 61, p. 878; E. fucicola Strömf., 70, p. 49. *α typica* is the most common, *β lubrica* (Rupr.) K. Rosenv. is rather common.

In all parts of the coast.

### Fam. **Sphacelariaceæ.**

**Sphacelaria britannica** Sauvag., 67, p. 50.

N. Icel., SW. Icel., S. Icel.

**Sphacelaria radicans** Harv., Sauvag., 67, p. 27, fig. 14; Reinke, 60, T. III, fig. 1; Kuck., Bemerk. I (47), p. 229, fig. 4.

E. Icel., N. Icel., SW. Icel., S. Icel.

**Sphacelaria olivacea** Pringsh., emend. Sauvag., 67, p. 54.

NW. Icel., SW. Icel., S. Icel.

**Chætopteris plumosa** (Lyngb.) Kütz., Sauvag., 67, p. 44; Strömf., 70, p. 52; K. Rosenv., 61, p. 903; Reinke, 59, Atlas T. 49—50.

E. Icel., N. Icel., NW. Icel., SW. Icel.

### Fam. **Punctariaceæ.**

**Omphalophyllum ulvaceum** K. Rosenv., 61, p. 872, fig. 19.

E. Icel.

**Punctaria plantaginea** (Roth) Grev., K. Rosenv., 61, p. 871; 62, p. 71; Strömf., 70, p. 50.

E. Icel., N. Icel., NW. Icel.

**Litosiphon filiformis** (Rke), Pogotrichum filiforme Rke (59), Atlas, p. 62, T. 41, figs. 13—25; K. Rosenv., 61, p. 869; Kuck., Ueber Polymorphie bei einigen Phæosporeen, Festschrift für Schwendener, p. 360.

E. Icel., N. Icel., SW. Icel., S. Icel.

**Isthmoplea sphærophora** (Harv.) Kjellm., 36, p. 276; Reinke (59), Atlas T. 30; Pylaiella curta Foslie, Nye havsalger, in Tromsø Museums Aarshefter, X, 1887, p. 181; Kjellman, 35, p. 85; Fosliea curta Rke, Atlas, p. 45.

E. Icel., NW. Icel., SW. Icel., S. Icel.

**Stictyosiphon tortilis** (Rupr.) Rke, Atlas, T. 31—32; K. Rosenv., 61, p. 868; Phloeospora tortilis Strömf., 70, p. 51; Phloeospora subarticulata Kjellman, 39, p. 78.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Phæostroma pustulosum** Kuckuck, Ueber einige neue Phæosporeen d. westl. Ostsee, Bot. Zeit. 1895, p. 182, T. VII; K. Rosenv., 62, p. 68, fig. 15.

E. Icel., NW. Icel., SW. Icel.

**Scytosiphon Lomentaria** (Lyngb.) J. Ag., K. Rosenv., 61, p. 863; 62, p. 62; Strömf., 70, p. 50.

In all parts of the coast.

**Phyllitis zosterifolia** Rke, 58, p. 61; K. Rosenv., 61, p. 862.

E. Icel., NW. Icel., SW. Icel., S. Icel.

**Phyllitis fascia** (O. F. Müll.) Kütz., K. Rosenv., 61, p. 862.

Gathered in all parts of the coast.

**Fam. Dictyosiphonaceæ.**

**Coilodesme bulligera** Strömf., 70, p. 48, T. II, figs. 9—12; K. Rosenv., 61, p. 862; 62, p. 61, fig. 13.

E. Icel., NW. Icel., SW. Icel.

**Dictyosiphon Ekmani** Aresch., Obs. phyc. 3 (7), p. 33.

SW. Icel.

**Dictyosiphon Mesogloia** Aresch., Obs. phyc. 3 (7); Reinke, 58, p. 64.

N. Icel.

**Dictyosiphon Chordaria** Aresch., Obs. phyc. 3 (7); Reinke, 58, p. 63; K. Rosenv., 61, p. 861; *Coilonema Chordaria* Strömf., 70, p. 51.

E. Icel., SW. Icel.

**Dictyosiphon corymbosus** Kjellm., 36, p. 267; Strömfelt, 70, p. 51.

N. Icel.

**Dictyosiphon hippuroides** (Lyngb.) Kütz.; Kjellm., 36, p. 268; Strömfelt, 70, p. 51.

N. Icel., NW. Icel., SW. Icel., S. Icel.

**Dictyosiphon foeniculaceus** (Huds.) Grev., Kjellman, 36, p. 269; K. Rosenv., 61, p. 859; Strömf., 70, p. 52.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Fam. Desmarestiaceæ.**

**Desmarestia viridis** (Müll.) Lam., K. Rosenv., 61, p. 859; *Dichloria viridis* Strömf., 70, p. 51.

Common around the coast of Iceland.

**Desmarestia aculeata** (L.) Lam., Strömf., 70, p. 51; K. Rosenv., 61, p. 857.

Common everywhere along the coast.

**Desmarestia ligulata** (Lightf.) Lam.

S. Icel.: Vestmannaeyjar (Ove Paulsen).

**Fam. Chordariaceæ.**

**Castagnea virescens** (Carm.) Thur., K. Rosenv., 62, p. 58; *Eudesme virescens* Strömf., 70, p. 47.

E. Icel., N. Icel., SW. Icel.

**Leathesia difformis** (L.) Aresch., Kjellm., 36, p. 252.

N. Icel., SW. Icel.

**Chordaria flagelliformis** (Müll.) Ag., Strömf., 70, p. 47; K. Rosenv., 61, p. 854.

Common everywhere along the coast.

Fam. **Chordaceæ.**

**Chorda tomentosa** Lyngb., Hydrophytologia Danica, p. 74; K. Rosenv., 61, p. 854.

E. Icel., N. Icel., SW. Icel.

**Chorda Filum** (L.) Stackh., K. Rosenv., 61, p. 853; Strömf., 70, p. 47.

E. Icel., N. Icel., NW. Icel., SW. Icel.

Fam. **Laminariaceæ.**

**Saccorrhiza dermatodea** (De la Pyl.) J. Ag.; K. Rosenv., 61, p. 850; *Phyllaria lorea* Strömf., 70, p. 42.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Laminaria saccharina** (L.) Lam., Kjellman, 36, p. 229; 35, p. 24; Strömf., 70, p. 42.

f. *typica*;

f. *linearis* J. Ag., Kjellman 36, p. 229; 35, p. 25; Strömf., 70, p. 42; Börgesen, 13, p. 451, fig. 85;

f. *latifolia* Kjellm., 35, p. 26; *Laminaria saccharina* f. *latisima* Kjellm., 36, p. 230; Strömf., 70, p. 43?

This species is common everywhere along the coast, especially the principal form; f. *linearis* is rarer and f. *latifolia* is only met with in E. Icel. and NW. Icel. where it occurs gregariously.

**Laminaria færoensis** Börges., 13, p. 454.

E. Icel., N. Icel.

**Laminaria nigripes** J. Ag., emend. K. Rosenv., 61, p. 842.

β *atrofulva* (J. Ag.) K. Rosenv. (l. c.); *Laminaria discolor*, *Laminaria nigripes* f. *oblonga* Strömf., 70, pp. 43—44.

E. Icel.

**Laminaria digitata** (L.) Lam., Kjellman, 36, p. 240; 35, p. 22; Strömf., 70, p. 45.

f. *genuina* Le Jol. 49; Kjellman, 35, p. 23;

f. *stenophylla* Harv. Phyc. Brit., T. 338; *Laminaria stenophylla* Strömf., 70, p. 45; J. Ag. De Lam., p. 18; Kjellm., 35, p. 24;

f. *cucullata* Le Jol., 49.

F. *genuina* is common everywhere; f. *stenophylla*: E. Icel., SW. Icel., S. Icel.; f. *cucullata*: E. Icel., NW. Icel.

*Laminaria hyperborea* (Gunn.) Foslie, 20, p. 42; Strömf., 70, p. 44;  
*Laminaria Cloustoni* Le Jol., 49, p. 577; fig., Fosl., 20, T. 1.

E. Icel., N. Icel., NW. Icel.; common in SW. Icel. and S. Icel.

*Alaria Pylaii* (Bory) J. Ag., emend. K. Rosenv., 61, p. 838; *Alaria Pylaii* and *Alaria membranifolia* Strömf., 70, p. 39.

f. *typica* K. Rosenv.;

f. *membranacea* (J. Ag.) K. Rosenv.

Common everywhere along the coast.

*Alaria esculenta* (L.) Grev., Kjellm., 36, p. 212; 35, p. 19; *Alaria esculenta*, *Alaria linearis* and *Alaria flagellaris* Strömf., 70, pp. 38—41; *A. flagellaris* K. Rosenv., 62, p. 49.

f. *australis* Kjellm.;

f. *fasciculata* Strömf.;

f. *pinnata* (Gunn.) Kjellm.

This species is exceedingly common everywhere along the coast.

### Fam. **Fucaceæ.**

*Fucus spiralis* L., Kjellm., 36, p. 202; Strömf., 70, p. 35; Børgesen, 13, p. 472; *Fucus Areschougii* Kjellm., 35, p. 11.

f. *typica*;

f. *borealis* Kjellm.

E. Icel., N. Icel., SW. Icel., S. Icel.

*Fucus inflatus* L., M. Vahl, Fl. Danica (30), T. 1127; Foslie, Krit. Fortegnelse, Tromsø Mus. Aarshefter, IX, p. 109; Kjellm., 35, p. 11; K. Rosenv., 61, p. 834; Børgesen, 13, p. 465; *Fucus evanescens* Strömf., 70, p. 35; *F. edentatus*, *F. furcatus* and *F. evanescens* J. Ag., 3, p. 40; *F. furcatus* Kleen, 43, p. 29; *F. edentatus* De la Pyl., 15, p. 84.

f. *typica*.

*F. furcatus* Kleen ex pte.; *F. evanescens* auct. ex pte.;

*F. edentatus* De la Pyl.;

fig. Flora Danica (30) T. 1127; Børgesen, 13, figs. 90 and 91.

f. *evanescens* (C. Ag.)

*F. evanescens* C. Ag., Sp. p. 92 et auct. partim.

f. *linearis* (Huds.) K. Rosenv., 61, p. 834; *F. linearis* Hudson  
 Flora anglica London 1762, Oeder Flora Danica (30) T. 351.

f. *exposita*.

*F. distichus* Lyngb. Hydr. Dan. (51) p. 6, exclus. syn.;

*F. distichus* a, *robustior* J. Ag. 3, p. 37, Kjellman 36, p. 210;

*F. inflatus* f. *disticha* Børgesen, 13, p. 465.

This species is common everywhere along the coast.



**Fucus serratus** L., Kjellm., 36, p. 196.

SW. Icel., S. Icel.

**Fucus vesiculosus** L., Kjellm., 36, p. 198; Strömf., 70, p. 34.

f. *typica*, fig. Harv. Phyc. Brit. T. 204.

f. *turgida* Kjellm.

f. *sphaerocarpa* J. Ag.

This species is common everywhere.

**Pelvetia canaliculata** (L.) Dec. et Thur., Strömf., 70, p. 38.

SW. Icel., S. Icel.

**Ascophyllum nodosum** (L.) Le Jol., K. Rosenv., 61, p. 832; *Ozothallia nodosa* Strömf., 70, p. 34.

Common along the coast.

## CHLOROPHYCEÆ.

### Fam. **Protococcaceæ.**

**Chlorochytrium Cohnii** Wright, K. Rosenv., 61, p. 963.

SW. Icel.

**Chlorochytrium inclusum** Kjellm., 36, p. 320, T. 31, figs. 8—17; K. Rosenv., 61, p. 963; 62, p. 119.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Chlorochytrium dermatocolax** Rke, 58, p. 88; K. Rosenv., 61, p. 964; Svedelius, 71, p. 72.

N. Icel., SW. Icel.

**Chlorochytrium Schmitzii** K. Rosenv., 61, p. 964; 62, p. 119.

SW. Icel.

**Codiolum Petrocelidis** Kuck., Bemerk. (47), p. 259, fig. 27.

SW. Icel.

**Codiolum gregarium** Al. Braun, *Algarum unicellularum genera nova et minus cognita*, Lipsiæ, 1855, p. 19; Börgesen, 13, p. 517.

E. Icel.

**Codiolum pusillum** (Lyngb.) Kjellm., Börgesen, 13, p. 518; *Vaucheria pusilla* Lyngb. Hydr. Dan. 51, p. 72, T. 22.

N. Icel.

### Fam. **Ulvaceæ.**

**Percursaria percursa** (Ag.) K. Rosenv., 61, p. 963.

SW. Icel.

**Enteromorpha aureola** (Ag.) Kütz., Tab. phyc., Vol. VI, T. 40, III; *Ulva aureola* Ag. Ic. alg. europ. (1), T. 29; *Capsosiphon aureolus* Gobi; *Ilea fulvescens* J. Ag., Ulvaceæ p. 114; ? *Solenia fulvescens* Ag., 2, p. 420; *Enteromorpha quaternaria* Ahlner in Wittr. et Nordstedt Alg. exsicc., Nos. 138 and 139.

N. Icel.

**Enteromorpha Linza** (L.) J. Ag., *Ulva enteromorpha* *a*, lanceolata Le Jol., 50, p. 42.

SW. Icel., S. Icel.

**Enteromorpha intestinalis** (L.) Link., emend. K. Rosenv., 61, p. 957; Börgesen, 13, p. 487.

f. *genuina* K. Rosenv. l. c. p. 957;

*Enteromorpha intestinalis* Strömf., 70, p. 52.

f. *micrococca* (Kütz.) K. Rosenv. l. c. p. 957.

f. *compressa* (L.) K. Rosenv. l. c. p. 958;

*Enteromorpha compressa* f. *typica* and

*E. complanata* f. *subsimplex* Strömf., 70, p. 53.

f. *minima* (Naeg.) K. Rosenv., l. c. p. 959;

*Enteromorpha minima* Strömf., 70, p. 53.

f. *prolifera* (O. F. Müller) Börgesen, 13, p. 490.

*Enteromorpha prolifera* K. Rosenv., 61, p. 960.

This species is common everywhere along the coast.

**Enteromorpha clathrata** (Roth) Grev., Kjellm., 36, p. 287; *Ulva clathrata* Le Jol., 50, p. 48 (partim); *Enteromorpha compressa* f. *racemosa* Strömf., 70, p. 53.

E. Icel., N. Icel., SW. Icel., S. Icel.

**Monostroma groenlandicum** J. Ag., K. Rosenv., 61, p. 954, fig. 53.

E. Icel., N. Icel., NW. Icel.

**Monostroma Grevillei** (Thur.) Wittr., emend. K. Rosenv., 61, p. 946.

var. *typica* K. Rosenv. l. c.

*Monostroma Grevillei* Wittr., 76, p. 57; Strömf. 70, p. 54 partim (e specim.).

var. *arctica* (Wittr.) K. Rosenv. l. c.

*Monostroma arcticum* Wittr., 76, p. 44; *Monostroma latisimum* Strömf., 70, p. 54.

var. *intestiniformis* K. Rosenv. l. c.

*Enteromorpha intestinalis* Strömf., 70, p. 58 partim (e spec.).

Var. *typica* and var. *arctica* are common along the coast; var. *intestiniformis*: E. Icel., SW. Icel.



**Monostroma undulatum** Wittr. 76, p. 46, T. III, fig. 9; K. Rosenv., 61, p. 945; *Monostroma Grevillei* Strömf., 70, p. 54 partim (e specim.).

In all parts of the coast.

**Monostroma fuscum** (Post. et Rupr.) Wittr., emend. K. Rosenv., 61, p. 940; *M. Blyttii*, Strömf. 70, p. 54.

*f. typica* is common along the coast; *f. grandis.*: E. Icel., N. Icel.

**Ulva Lactuca** L., K. Rosenv. 61, p. 839; Strömf., 70, p. 54.

N. Icel., NW. Icel., SW. Icel., S. Icel.

### Fam. **Prasiolaceæ.**

**Prasiola polyrrhiza** (K. Rosenv.).

*Gayella polyrrhiza* K. Rosenv., 61, p. 936;

*Prasiola crispa* subsp. *marina* Börgesen, 13, p. 482;

*Prasiola crispa f. submarina* Wille, 73, p. 13.

SW. Icel., S. Icel.

**Prasiola furfuracea** (Mert.) Menegh. Imhäuser, 29, p. 266; Foslie Contrib., I, p. 127; Börgesen, 13, p. 486.

E. Icel., N. Icel., SW. Icel.

**Prasiola stipitata** Suhr; Imhäuser, 29, p. 272; Kjellman, 36, p. 303.

E. Icel., N. Icel., SW. Icel., S. Icel.

### Fam. **Ulothricaceæ.**

**Ulothrix consociata** Wille, 73, p. 25.

var. *islandica* H. Jónss.

N. Icel.

**Ulothrix subflaccida** Wille, 73, p. 29.

E. Icel., N. Icel.

**Ulothrix pseudoflacca** Wille, 73, p. 22, T. II, figs. 64—81.

E. Icel., SW. Icel., S. Icel.

**Ulothrix flacca** (Dillw.) Thur., K. Rosenv., 61, p. 935, fig. 44; Wille, 73, p. 18, T. I—II, figs. 54—63.

Common around the coast of Iceland.

### Fam. **Chætophoraceæ.**

**Pseudendoclonium submarinum** Wille, 73, p. 29, T. III, figs. 101—134.

E. Icel.

**Entoderma Wittrockii** (Wille) Lagerh., K. Rosenv., 61, p. 934.

N. Icel., SW. Icel., S. Icel.

**Acrochæte parasitica** Oltm. Bot. Zeit. 1894, p. 208; K. Rosenv., 62, p. 114.

SW. Icel.

**Acrochæte repens** Pringsh., Beiträge p. 2, T. II; Huber, 28, p. 306.  
NW. Icel.

**Bolbocoleon piliferum** Pringsh., Beiträge p. 2, T. II; Huber, 28, p. 308, pl. 13, figs. 8—12.

E. Icel., N. Icel., NW. Icel.

### Fam. **Mycoideaceæ.**

**Ulvella fucicola** K. Rosenv., 61, p. 926, fig. 40. *Pseudopringsheimia fucicola* (Rosenv.) Wille in Engler u. Prantl: Die natürlichen Pflanzenfamilien, Nachträge zu I. Theil, Abtheil 2, p. 89.

E. Icel., N. Icel., SW. Icel., S. Icel.

**Pringsheimia scutata** Rke, 58, p. 81, Atlas T. 25.

NW. Icel., SW. Icel.

**Ochlochæte ferox** Huber, 28, p. 291, T. X; K. Rosenv. 61, p. 931, fig. 41.

N. Icel.

### Fam. **Cladophoraceæ.**

**Urospora mirabilis** Aresch., K. Rosenv., 61, p. 918, fig. 35; 62, p. 106.  
Common along the coast.

**Urospora Hartzii** K. Rosenv., 61, p. 922, fig. 38.

E. Icel., SW. Icel., S. Icel.

**Urospora Wormskioldii** (Mert.) K. Rosenv., 61, p. 920, fig. 36.

In all parts of the coast.

**Chætomorpha tortuosa** (Dillw.) Kleen, K. Rosenv., 61, p. 917.

E. Icel., N. Icel., SW. Icel.

**Chætomorpha Melagonium** (Web. et Mohr) Kütz., K. Rosenv., 61, p. 917; Strömf., 70, p. 55.

Probably common along the coast of Iceland.

**Rhizoclonium riparium** (Roth) Harv., K. Rosenv., 61, p. 913; 62, p. 103.

f. *polyrhiza* K. Rosenv., l. c. p. 913.

f. *valida* Fosl., K. Rosenv., l. c. p. 915.

f. *implexa* (Dillw.) K. Rosenv., l. c. p. 915.

E. Icel., N. Icel., SW. Icel.

**Spongomorpha vernalis** (Kjellm.) Wille, *Acrosiphonia vernalis* Kjellm., 41, p. 82.

SW. Icel.

**Acrosiphonia albescens** Kjellm., 41, p. 55, T. IV, fig. 21; Börgesen, 13, p. 507, fig. 103; *Spongomorpha arcta* Strömf., 70, p. 54, ex pte. Common along the coast of Iceland.

**Acrosiphonia incurva** Kjellm. 41, p. 61.

Common along the coast.

**Acrosiphonia hystrix** (Strömf.) H. Jónss., 31.

f. *typica* H. Jónss., *Spongomorpha hystrix* Strömf., 70, p. 54, *Cladophora diffusa* Strömf., 70, p. 55 ex pte. (e specim.); *Cladophora* (*Spongomorpha*) *arcta*  $\gamma$  *hystrix* K. Rosenv., 61, p. 907.

f. *littoralis* H. Jónss.

E. Icel., N. Icel., NW. Icel., SW. Icel.

**Acrosiphonia flabelliformis** H. Jónss., 31.

S. Icel.

**Acrosiphonia penicilliformis** (Fosl.) Kjellm., 41, p. 80 forma.

E. Icel.

**Cladophora rupestris** (L.) Kütz., K. Rosenv., 61, p. 909; Strömf., 70, p. 55.

N. Icel., NW. Icel., SW. Icel., S. Icel.

**Cladophora hirta** Kütz., Kjellm., in Wittr. et Nordstedt Exsicc., No. 1041.

SW. Icel., S. Icel.

**Cladophora sericea** (Huds.) Aresch., 8, p. 194, forma.

N. Icel., SW. Icel., S. Icel.

**Cladophora glaucescens** (Griff.) Harv., Phyc. Brit. T. 196; Le Jol. Alg. mar. d. Cherb. Exsicc., 66.

SW. Icel.

**Cladophora gracilis** Kütz., Kjellm. in Wittr. et Nordstedt Exsicc., No. 1040.

E. Icel., N. Icel., SW. Icel.

### Fam. **Gomontiaceæ.**

**Gomontia polyrrhiza** (Lagerh.) Born. et Flah. sur deux nouv. gen. d'Algues perfor. Journ. de Bot. Tom. II, 188, p. 163.

E. Icel., N. Icel., NW. Icel., SW. Icel.

Fam. **Phyllosiphonaceæ.**

**Ostreobium Queketti** Born. et Flah., Sur quelques plantes vivant dans le test calcaire des mollusques, p. 15, pl. IX, figs. 5—8.

E. Icel., N. Icel., NW. Icel., SW. Icel.

## CYANOPHYCEÆ.

Fam. **Chamæsiphonaceæ.**

**Pleurocapsa amethystea** K. Rosenv., 61, p. 967, var.

E. Icel., N. Icel.; common in NW. Icel., SW. Icel. and S. Icel.

Fam. **Oscillatoriaceæ.**

**Plectonema norvegicum** Gomont, Bull. de la Soc. bot. de France, tome XLVI, 1899.

N. Icel.

**Phormidium autumnale** (Ag.) Gomont, emend. Johs. Schmidt, 68, pp. 348 and 410.

E. Icel.

**Spirulina subsalsa** Ørsted, Beretning om en Excursion til Trindelen, Krøyers Tidsskrift 3. Bd., pp. 566, 1842.

N. Icel., S. Icel.

Fam. **Rivulariaceæ.**

**Calothrix scopulorum** (Web. et Mohr) Ag., emend. Johs. Schmidt, 68, pp. 390 and 414.

E. Icel., N. Icel.

**Rivularia atra** Roth, Catalecta botanica, III, p. 340, 1806.

SW. Icel.

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## II. LIFE-CONDITIONS OF THE MARINE ALGAL VEGETATION.

### 1. THE NATURE OF THE COAST.

THE coast of Iceland consists partly of rock and partly of sand. The rocky coasts are rich in algal vegetation, while the sandy coast is most frequently a "desert." Here and there vegetation may be found, however, on the sandy coast, where this is not exposed to violent movement during any length of time. The vegetation then consists of short-lived species.

The Rocky Coast. This abounds in indentations of various size: inlets, fjords and bays. The size of the fjords varies greatly; for example, the largest, Faxaflói, is ten geographical miles long and twelve geographical miles broad, and Breiðfjörður is eighteen geographical miles long and ten geographical miles broad. The smaller fjords, on the other hand, are short and narrow indentations. Thus, owing to the indentations on the coast, the exposure is apt to vary greatly. The extreme points and the outer portions of the fjords have, as a rule, an exposed position, while in the interior of the fjord the water is generally calm.

The rocks on the coast consist of basalt; in some places, however, tuff-coasts exist, and especially on the south coast. The fjord-coasts of Iceland, which comprise South-west, North-west, North and East Iceland, are mainly composed of basalt. The basalt varies considerably but, as far as I have seen, it has no significance as regards the distribution of the species, and no difference is seen, for example, in the vegetation on the dolerite and the ordinary basalt coasts. What is of prime importance to the vegetation is not the rock itself but the nature of its surface. The surface is, as a rule, very uneven, being eroded by water, weather and wind, and furrowed by numerous fissures. Its nature is, therefore, such that the algæ can easily attach themselves to it.

The rocky coast is, as a rule, of solid rock, consisting of preglacial basaltic lava. Postglacial basaltic lava is found, nevertheless, in some places, as for example on Snæfellsnes. In many places, large stretches of the coast are covered with debris (Urð) from the mountains. Where the debris or the new lava predominates the surface is generally very uneven, and one then finds distinct elevations with large and small depressions interposed; such a coast is usually covered with an abundant and multifarious algal vegetation, if the conditions are in other respects favourable to the existence of algæ.

There is no range of skerries (Skærgaard) as there is, for example, on the coast of Norway. Yet a number of islands and rocks occur in the fjords, especially in Breiðfjörður. In this fjord are found indications of a range of skerries running parallel with the coast and along a considerable stretch of it, and marking the outward limit of the *Zostera*-vegetation.

The Sandy Coast. Almost the entire coast of S. Iceland is sandy shore or gravel shore. As a rule, such bottoms afford a mobile substratum because each wave which breaks on the beach shifts the particles backwards and forwards. A sandy coast is also met with, here and there, in other parts of the country, but is then found, as a rule, alternating with rocky parts; thus, the sandy or gravelly shore is often predominant at the head of small indentations which at the sides are bounded by projecting masses of rocks.

Clayey Shore is also found fairly frequently in the interior of the fjords.

The rocky coast is, as a rule, abundantly overgrown, and this is frequently the case also with the sublittoral gravel-bottom, while the sand and gravel bottoms laid bare periodically by the shifting tide are not, as a rule, overgrown, and, in any case, only with short-lived species. On clayey and muddy bottoms, on the other hand, algæ are seldom or never found, while *Zostera* often covers such a bottom and forms submarine "green meadows."

Despite the small "desert" areas, one may say that the coasts are covered with a zone of continuous algal vegetation — if we exclude the eastern portion of S. Iceland. This algal zone varies greatly in width, accommodating itself to the precipitousness of the coast. In a bay as shallow as Faxaflói the algal vegetation has a great extension seawards, while it is far more limited, for example, on the steeply descending submarine declivities in the fjords of the east coast.



## 2. THE OCEAN.

As regards the ocean, the chief points are its movements, temperature and salinity.

### A. The Movements of the Ocean.

These are — tides, waves and currents. All these movements of the ocean are of very great importance to the life of the algæ.

a. Tides. By the alternate rise and fall of the tide a part of the shore is laid bare, and the vegetation growing there must then be capable of maintaining life in the air for a longer or shorter period. Those plants which grow highest up in the zone thus left dry, are exposed during the greater part of the period between the one flood-tide and the next, or for about 10—11 hours in every 12. The plants occurring lowest down in the zone, on the other hand, are not exposed during spring-tide for more than one hour in every 12, and they are submerged the whole time during neap-tide. The upper limit of the algal vegetation is, moreover, dependent on how high the tide rises, i. e. the height of the flood-tide.

**The Height of the Flood-tide.** The following data regarding the height of the flood-tide are taken from “Den islandske Lods” (1903) and from the alterations and additions to it which have been published. The height of the flood-tide is greatest in SW. Iceland and least in E. Iceland. The height of the flood-tide at spring-tide is recorded as being about 14 feet from Reykjavík (SW. Iceland), 10—11 feet from NW. Iceland, 5—5½ feet from the north coast and 5 feet from E. Iceland.

In many places there is a great difference as regards the height of the flood-tide during the spring and neap tides. To illustrate this more fully I give the following figures from some localities on the different parts of the coast: —

	Spring-tide	Neap-tide
South Iceland, Vestmannaeyjar .....	8—10 feet	4 feet
— Eyrarbakki .....	10 -	6 -
South-west Iceland, Reykjavík .....	cir. 14 -	4 -
— Stykkishólmur .....	12 -	6 -
North-west Iceland, Dyrafjörður .....	11 -	5—6 -
North Iceland, Akureyri .....	5½ -	1½ -
East Iceland, Djúpivogur .....	7½ -	2½ -

From Elliðaey near Stykkishólmur in SW. Iceland the height of the flood-tide during spring-tide is recorded as being 14 feet and

during neap-tide 7 feet, and it is also recorded from the latter place that the low-water at neap-tide lies about 3 feet above that at spring-tide.

When extraordinary conditions prevail the height of the flood-tide may be still greater; thus, 18—19 feet has been recorded from Reykjavík and 18 feet from Stykkishólmur.

From this it is seen that the height of the flood-tide varies greatly, which must necessarily affect the algal vegetation in several respects, especially as concerns the upper limit of its growth. Thus there is a great difference in the highest flood-mark (at spring-tide) and in the lowest flood-mark (at neap-tide). The tidal wave or the tide, moreover, shows irregularities, because neither the highest flood-mark (spring) nor the lowest flood-mark (neap-tide) is constant. The limit of the flood-tide fluctuates perpetually between a high-mark and a low-mark. The high-mark or the highest limit of the flood-tide is seen distinctly on rocky coasts from the action of the sea on the rock. On flat coasts, the high-mark can be distinguished by detached algæ and various other bodies which accompany the tidal wave and remain at the highest level reached by the water. This high-mark lies considerably higher than the upper limit of the algal vegetation.

The low-mark is not as easy to distinguish as the high-mark, but it will almost coincide with the upper limit of the *Pelvetia-Fucus spiralis* association. Above this the *Bangia* association (*Ulothrix*, *Bangia*, and others) is found, the extreme limit of which will almost coincide with an average water-level which, however, does not lie midway between low-mark and high-mark, but rather nearer the former. The upper limit of the algal vegetation thus lies somewhat above the limit of the flood-tide at neap-tide. The same rule holds good, of course, on a very exposed coast. That the place is exposed means that there is a heavy swell, which causes the sea to rise higher up on the coasts, both at neap-tide and at spring-tide.

By the upper limit of the marine algal vegetation is meant that boundary line above which marine algæ do not occur in the form of associations; on the other hand, no account is taken of single individuals or groups of individuals being found higher up, in crevices or pools, as such an occurrence must be considered accidental, because they are carried up to this height with the high water or by far-reaching breakers. They do live, of course, but do not thrive, and have evidently gone beyond their real area of distribution. In



this respect, however, those species should be excepted which can grow both in salt and in fresh water, as for example, *Enteromorpha intestinalis* (the principal form) and others. Naturally, such species cannot be taken into account when defining the upper limit of growth of marine algal vegetation.

If we compare the upper limit of the marine algal vegetation in Iceland with the same limit in Greenland it appears that they agree almost completely, as Rosenvinge (63, p. 89) sets the limit in Greenland almost at flood-mark at neap-tide. On the other hand there seems to be an incongruity with the Færøes, as Børgesen (11 and 12) sets the limit far above highest flood-mark in exposed places and almost at uppermost flood-mark in sheltered places.

If we institute comparisons with more distant coasts, for instance with the west coast of Sweden, the algal vegetation of which has lately been described by Kylin (43), we find that, as regards the upper limit, the case is the same as in Iceland, that is, the upper limit is coincident with an average water-level which lies higher in exposed places than in sheltered ones.

In Iceland, indeed, on a very exposed coast, marine algæ can be found rather high up, and if the sea is smooth and calm they may appear to be rather far away from the water; but on returning to the same place when the sea is in motion we see that it washes over them, and we no longer think it strange that they grow in so high a position. While the marine algal vegetation, as mentioned before, only extends upwards to an average water-level, it frequently happens on flat coasts that the land-vegetation is submerged at spring-tide. This occurs both in the interior of the fjords and on the lower islands, and may generally be distinguished by the appearance and the components of the vegetation; marine algæ, however, do not occur among such vegetation.

Some phanerogams, e. g. *Atriplex*, *Mertensia*, *Cakile*, etc., also grow below the upper limit of the littoral zone. According to Rosenvinge it happens in Greenland also that the land-vegetation is submerged at spring-tide.

b. The Swell. Here, those inequalities in the surface of the ocean which in every-day language are called waves, and that volume of water which, with a sea-wind is forced in towards the land, are treated collectively. The volume of water which is driven towards the coast by a sea-wind raises the water-level. While the tidal wave rises, the sea moved by the wind works together with

it, but when the water falls it counteracts the tidal wave; this circumstance is of great importance on exposed coasts where the wind blows frequently, as it shortens the period of desiccation. These movements in the sea are naturally somewhat irregular, but the irregularities are quite equalized in the long run, and therefore the effect of these movements may very well be regarded as constant. The high-mark which the water leaves on the coasts is due to the tide and to these movements jointly.

A frequent sea-wind has a favourable effect on the vegetation in the zone laid bare by the tide, as mentioned above, but where a frequent land-wind is blowing the effect is the reverse, as this counteracts the rise of the tidal wave and accelerates its fall, whereby the period of desiccation is prolonged.

The effect of the waves beating on the algæ is great. In exposed places, that is in places where the swell is heavy, the plants must be able to withstand the drag of the waves. The species which grow in these places therefore have a tough, leathery and narrow frond, whereas species in quiet waters have a delicate frond, often broad and brittle. The consistency of the frond thus accommodates itself to the force of the beat of the waves, and in partially exposed places, or in places where the beat of the waves is not strong, but yet fairly considerable, we find the consistency of the frond to be about midway between what it is in exposed and in calm places.

Like all other movements of the sea, the waves also are of great importance to the algal vegetation by the fact of their constantly providing fresh particles of water.

c. Currents (Fig. 2). Along the coast of Iceland the warm water of the Atlantic Ocean meets the cold water of the Arctic Ocean. The Gulf Stream washes the south coast of the country and sends an arm northward along SW. Iceland and NW. Iceland, and along the entire north coast warm water can be traced (the eastern arm of the Irminger Current) to Langanæs; and from thence the arm turns toward the south along the coast of E. Iceland (Nielsen, 52, p. 13), where it mixes with water from the East Iceland polar current, which comes from the Norwegian Sea (Helland-Hansen and Nansen, 27, p. 287, where the current is called the East Iceland Arctic Current). In this manner characteristic coast-water arises at E. Iceland. Regarding this Nielsen (52, p. 13) writes that the Irminger Current "gives the waters over the coast shoal of East

Iceland a physiognomy different from that of the surrounding sea, the distribution of temperature being different even if the temperature is not in any important degree higher than in the East Icelandic polar current itself."

The conditions of the currents in N. and E. Iceland are evidently very complicated, and only the direction of the current of the warm water has been given above in outline, but as the observations are so few it is difficult to form an opinion as to how the condi-



Fig. 2. Map of Currents.  
(Helland-Hansen and Nansen.)

tions of the currents along these coasts vary in other respects from year to year or according to the seasons.

Further, other current-movements occur in the coast-water which may be deemed to be of importance to the vegetation, that is, such movements as are due to varying specific gravity. In the summer (Nielsen, 52, p. 8) the surface-water along the coast is lighter on account of its mixing with fresh water. A surface-current from the coast outwards then arises, and an under-current from the depth towards the coast. In the winter the surface-water along the coast becomes heavier owing to cooling, and sinks. Then a surface-current from the ocean towards the coast arises, and an under-current from the coast towards the depth.

## B. The Temperature of the Water.

a. The temperature of the ocean around the coasts is not sufficiently known, and consequently the mean values cannot be given. I give, therefore, as an example, some actual measurements, as even these may be instructive in several respects. As regards NW. Iceland, N. Iceland and the northernmost part of the coast of E. Iceland I rely on the measurements carried out during the year 1904 on board the Danish Deep Sea Exploration ship "Thor" (Nielsen, 52).

### East Iceland just south of Langanes.

April 24. St. 15, 66° 09' N. lat.  
14° 26' W. long.

178 m.

Depth (m.)	Temp. (C°)	Salinity ‰
0	0.63	34.70
25	0.74	34.72
50	0.73	34.72
100	0.71	34.72

Aug. 12. St. 99, 66° 10' N. lat.  
14° 29' W. long.

189 m.

Aug. 13. St. 100, 66° 16' N. lat.  
13° 36' W. long.

284 m.

Depth (m.)	Temp. (C°)	Salinity ‰	Depth (m.)	Temp. (C°)	Salinity ‰
0	7.60	34.43	0	8.57	34.51
10	7.53	34.44	10	8.31	34.51
25	6.90	34.51	25	6.00	34.69
50	5.89	34.69	35	4.87	—
75	5.20	34.78	50	3.58	34.88
100	4.61	34.85	75	3.32	34.91
			100	3.08	34.92

### North Iceland east of Eyjafjörður.

April 23. St. 14, 66° 32' N. lat.  
17° 50' W. long.

175 m.

July 21. St. 74, 66° 33' N. lat.  
18° 10' W. long.

75 m.

Depth (m.)	Temp. (C°)	Salinity ‰	Depth (m.)	Temp. (C°)	Salinity ‰
0	1.50	34.85	0	8.40	33.91
25	1.65	34.87	10	7.49	34.79
50	1.68	34.87	17	7.19	34.85
100	1.70	34.85	21	6.34	—
			25	5.49	34.82
			50	5.06	34.87
			73	4.81	34.88

July 21. St. 73, 66° 14' N. lat.  
17° 28' W. long.

Aug. 15. St. 104, 66° 14' N. lat.  
17° 28' W. long.

197 m.			226 m.		
Depth (m.)	Temp. (C°)	Salinity ‰	Depth (m.)	Temp. (C°)	Salinity ‰
0	10.5	31.62	0	8.60	34.27
10	7.12	31.11	10	8.52	34.27
17	6.52	34.43	25	7.84	34.47
25	6.74	34.69	35	6.71	34.60
50	5.95	34.76	50	5.90	34.82
75	5.37	34.88	75	5.63	34.86
100	4.84	34.96	100	5.40	34.91

### North Iceland west of Eyjafjörður.

April 23. St. 13, 66° 30' N. lat.  
20° 47' W. long.

Aug. 23. St. 106, 66° 19' N. lat.  
20° 38' W. long.

220 m.			222 m.		
Depth (m.)	Temp. (C°)	Salinity ‰	Depth (m.)	Temp. (C°)	Salinity ‰
0	2.34	34.94	0	4.50	32.18
25	2.41	34.96	10	4.70	32.94
50	2.47	34.97	17.5	5.65	33.53
100	2.46	34.97	25	6.30	33.89
			30	6.11	33.93
			37.5	4.42	33.95
			50	4.27	34.34
			62.5	5.45	34.75
			75	5.62	34.83
			90	5.84	34.94
			100	6.12	35.05

April 23. St. 12, 66° 31' N. lat.  
22° 25' W. long.

62 m.		
Depth (m.)	Temp. (C°)	Salinity ‰
0	1.20	34.76
40	1.05	34.81
60	1.05	34.81

June 2. St. 51, 66° 29' N. lat.  
22° 25' W. long.

Aug. 24. St. 107, 66° 30' N. lat.  
22° 27' W. long.

62 m.			46 m.		
Depth (m.)	Temp. (C°)	Salinity ‰	Depth (m.)	Temp. (C°)	Salinity ‰
0	3.52	34.67	0	8.91	34.58
10	3.49	34.67	10	8.96	34.58
25	3.49	34.70	20	8.93	34.58
60	3.49	34.70	30	8.91	34.58
			45	8.72	34.61



## North-west Iceland.

April 22. St. 10,  $66^{\circ} 17' \text{ N. lat.}$   
 $23^{\circ} 14' \text{ W. long.}$

125 m.		
Depth (m.)	Temp. (C°)	Salinity ‰
0	1.42	34.69
50	2.82	34.99
120	2.94	35.05

April 23. St. 11,  $66^{\circ} 33' \text{ N. lat.}$   
 $23^{\circ} 37' \text{ W. long.}$

84 m.		
Depth (m.)	Temp. (C°)	Salinity ‰
0	2.40	34.97
82	2.97	—

June 2. St. 52,  $66^{\circ} 20' \text{ N. lat.}$   
 $23^{\circ} 31' \text{ W. long.}$

142 m.		
Depth (m.)	Temp. (C°)	Salinity ‰
0	4.25	34.92
10	4.24	34.92
25	4.17	34.98
50	4.19	34.99
75	4.25	34.99
100	4.34	35.01

Aug. 24. St. 108,  $66^{\circ} 19' \text{ N. lat.}$   
 $23^{\circ} 27' \text{ W. long.}$

115 m.		
Depth (m.)	Temp. (C°)	Salinity ‰
0	9.42	34.67
10	9.52	34.66
25	9.46	34.66
35	9.39	—
50	8.16	34.85
75	7.37	34.91
110	6.76	35.01

Almost at the boundary between NW. Iceland  
and SW. Iceland.

June 26. St. 61,  $65^{\circ} 32' \text{ N. lat.}$   
 $24^{\circ} 34' \text{ W. long.}$

41 m.		
Depth (m.)	Temp. (C°)	Salinity ‰
0	8.17	34.13
5	7.93	34.25
10	7.77	34.34
20	7.66	34.50
40	7.61	34.52

Aug. 26. St. 109,  $65^{\circ} 29' \text{ N. lat.}$   
 $24^{\circ} 37' 5 \text{ W. long.}$

43 m.		
Depth (m.)	Temp. (C°)	Salinity ‰
0	10.26	34.54
10	10.20	34.54
15	10.20	34.53
25	10.21	34.54
40	10.21	34.57

The measurements recorded show distinctly the range of the temperature in April and August, 1904. By taking successively the stations 11 (April 23rd), 13 (April 23rd), 14 (April 23rd) and 15 (April 24th) it is distinctly seen how the temperature of the surface-water of the ocean along the north coast of Iceland decreases from west to east, as shown by the following figures: —

St. 11	St. 13	St. 14	St. 15
2.40°	2.34°	1.50°	0.63°

A similar decrease of warmth from west to east, but in a far lesser degree, appears to occur in the month of August.

Station 106 (Aug. 23rd) shows a much lower temperature than

was to be expected, which is unquestionably due to the water from the East Greenland polar current, as the ice was still, or had recently been, in the neighbourhood.

### South Iceland.

From the ocean south of Iceland there are also measurements to hand carried out on board the "Thor" (Nielsen, 53).

#### South coast west of Dyrhólaey.

July 8. St. 63, 1904,  $63^{\circ} 32' \text{ N. lat.}$   
 $21^{\circ} 30' \text{ W. long.}$  July 9. St. 64, 1904,  $63^{\circ} 08' \text{ N. lat.}$   
 $21^{\circ} 30' \text{ W. long.}$

106 m.			662 m.		
Depth (m.)	Temp. (C°)	Salinity ‰	Depth (m.)	Temp. (C°)	Salinity ‰
0	10.89	35.14	0	10.44	35.16
25	9.77	35.14	25	10.18	35.16
50	8.06	35.14	50	8.07	35.16
104	7.85	35.16	100	7.67	35.19

July 12. St. 67, 1904,  $63^{\circ} 16' \text{ N. lat.}$   
 $19^{\circ} 17' \text{ W. long.}$  Aug. 31. St. 114, 1904,  $63^{\circ} 25' \text{ N. lat.}$   
 $20^{\circ} 03' \text{ W. long.}$

765 m.			150 m.		
Depth (m.)	Temp. (C°)	Salinity ‰	Depth (m.)	Temp. (C°)	Salinity ‰
0	11.45	35.03	0	11.70	34.49
25	10.09	35.14	10	11.70	34.51
50	8.14	35.21	20	11.55	34.65
100	7.77	35.21	30	11.31	34.92
			40	11.31	35.03
			45	10.95	35.07
			50	9.78	35.04
			75	7.97	35.22
			100	7.74	35.22

#### South coast east of Dyrhólaey.

May 23. St. 46, 1905,  $63^{\circ} 51' \text{ N. lat.}$   
 $16^{\circ} 25' \text{ W. long.}$

60 m.

Depth (m.)	Temp. (C°)	Salinity ‰
0	7.51	34.81
10	7.14	34.99
25	6.87	35.14
58	6.90	35.16

There are moreover some notes, given by Knudsen (44), on the temperature and salinity of the surface-water of the ocean south of Iceland. They are based upon the measurements carried out on



board the mail steamer "Laura" on its route from Scotland to Iceland during the years 1897—1904.

Between longitude  $17^{\circ}$  and  $18^{\circ}$ , near the coast of Iceland, in a south-easterly direction from Dyrhólaey, the mean temperature of the year (1897—1904) is stated (44) to be  $8.8^{\circ}$  and the mean salinity during the same period 35.19.

The main features regarding the temperature of the ocean around Iceland then are as follows — At the south coast warm, pure Atlantic water of a high (above  $35^{\circ}/_{\text{oo}}$ ) and somewhat varying salinity occurs; at SW. Iceland there is a somewhat similar sea; at NW. Iceland and N. Iceland there is Atlantic water mixed with cold water of low salinity from the East Greenland polar current; and lastly, at E. Iceland Arctic water occurs (with a temperature of  $0^{\circ}$  to  $2^{\circ}$  and salinity from 34.6 per cent. to 34.9 per cent. [Helland-Hansen and Nansen, 27, p. 287]): the East Iceland polar current mixed with water from the Atlantic current.

The change of temperature in the surface-layers of the water, the cooling process during winter and the heating process during summer, reaches down almost as deep as the algal vegetation, and is consequently of no slight importance to the latter.

b. The Temperature in the Fjords. Respecting the temperature of the surface-water of the ocean throughout the year information is given in the "Meteorologisk Aarbog" (Meteorological Yearbook) regarding three stations in Iceland: Papey, Grímsey and Stykkishólmur. The following figures show the seasons' mean temperature of the ocean for a period of five years (1902—1906), chosen arbitrarily. Grímsey is omitted, however, as the observations there have often been incomplete.

	Winter	Spring	Summer	Autumn
Papey (E. Iceland) . . . . .	$0.9^{\circ}$	$1.7^{\circ}$	$6.0^{\circ}$	$4.3^{\circ}$
Stykkishólmur (SW. Iceland). . . . .	$0.4^{\circ}$	$1.8^{\circ}$	$9.6^{\circ}$	$6.4^{\circ}$
Vestmannaeyjar <sup>1</sup> (S. Iceland). . . . .	$4.1^{\circ}$	$6.1^{\circ}$	$10.4^{\circ}$	$7.0^{\circ}$

The winter in Papey is warmer than in Stykkishólmur, and the monthly mean temperatures during the winter, of the period mentioned, are there all positive; while in Stykkishólmur, February ( $-0.8$ ) and March ( $-0.2$ ) have negative numbers. The summer is much warmer

<sup>1</sup> The figures for the Vestmannaeyjar constitute the mean of the period from July 1st, 1877 to Dec. 31st, 1906. According to Þorvaldur Thoroddsen, Lysing Islands, 2. Bd., pp. 350—351, Kaupmannahöfn 1910.

in Stykkishólmur. A comparison of these two places is, however, not equivalent to a comparison between E. Iceland and SW. Iceland, the situation of the stations being quite different. Papey is an island lying isolated in the ocean; Stykkishólmur, on the other hand, is a good example of the thermal conditions existing in the calm fjords.

Regarding the temperature at various depths in the interior of the fjords some observations are to hand made during the summer. These are, however, too few and scattered to be given in mean values. I give, therefore, as an example, some actual measurements from different parts of the coast of Iceland.

In East Iceland the measurements of temperature were carried out on board the Survey vessel "Diana" (Fisheries' Report ("Fiskeri-Beretning") for the financial year 1899—1900), and of these the following are given: —

	Depth in fathoms	Temp. (C°)
Hellisfjörður ( <sup>19</sup> / <sub>5</sub> ) . . . . .	0	1.7
	10	1.6
Ladmundarfjörður ( <sup>7</sup> / <sub>6</sub> ). . . . .	0	5.0
	cir. 33	1.5
Bakkafjörður ( <sup>13</sup> / <sub>6</sub> ) . . . . .	0	8.0
	7	2.5
Vopnafjörður ( <sup>20</sup> / <sub>6</sub> ) . . . . .	0	4.5
	13 <sup>1</sup> / <sub>2</sub>	1.8
Finna fjörður ( <sup>17</sup> / <sub>6</sub> ) . . . . .	0	3.8
	8 <sup>1</sup> / <sub>2</sub>	2.4
Finna fjörður ( <sup>18</sup> / <sub>7</sub> ) . . . . .	0	6.5
	5	6.3
Breiðdalsvík ( <sup>16</sup> / <sub>8</sub> ) . . . . .	0	4.6
	Bottom	4.3

The low bottom-temperature in June is probably due to the East Iceland polar current.

In addition to these Sæmundsson<sup>1</sup> has published the following measurements of the temperature and salinity of the surface of the fjords in East Iceland.

	Temp. of the surface (C°)	Salinity ‰	
Djúpivogur ( <sup>15</sup> / <sub>8</sub> ) . . . . .	9.0	29.47	high-water.
— . . . . .	7.4	33.14	low-water.
Fáskrúðsfjörður ( <sup>19</sup> / <sub>8</sub> ) . .	10.0	33.67	at Búðir.
— . .	9.5	32.23	at Mjóeyri.
— . .	9.4	33.54	at Brimnes.
— . .	9.0	32.19	at Höfði.
— ( <sup>20</sup> / <sub>8</sub> ) . .	7.0	34.71	at Kolfreyjusstaður.

<sup>1</sup> Bjarni Sæmundsson, Fiskirannsóknir, 1898, Andvari, XXIV. árg.

	Temp. of the surface (C°)	Salinity ‰	
Vattarnes ( <sup>21</sup> / <sub>8</sub> ) . . . . .	8.5	34.58	near land.
Eskifjörður ( <sup>13</sup> / <sub>8</sub> ) . . . . .	9.3	1.31	in the fjord, after rain.
— ( <sup>24</sup> / <sub>8</sub> ) . . . . .	5.0	6.73	near land, outflowing current.
— — . . . . .	5.0	23.71	out in the fjord, in outflowing current.
— — . . . . .	5.0	34.45	out in the fjord, in inflowing current.
Norðfjörður ( <sup>27</sup> / <sub>8</sub> ) . . . . .	7.5	34.45	near land.
Mjóifjörður ( <sup>30</sup> / <sub>8</sub> ) . . . . .	6.5	33.00	at Brekka.
Seyðisfjörður ( <sup>1</sup> / <sub>8</sub> ) . . . . .	9.5	9.23	head of the fjord.
— ( <sup>8</sup> / <sub>8</sub> ) . . . . .	7.5	22.01	—
— — . . . . .	8.0	22.01	out in the fjord.
— — . . . . .	8.5	25.04	—
— — . . . . .	7.8	30.65	—
— — . . . . .	7.5	31.96	—
— ( <sup>31</sup> / <sub>8</sub> ) . . . . .	7.0	34.45	at Skálanes.
— ( <sup>1</sup> / <sub>9</sub> ) . . . . .	7.0	34.45	at Brimnes.
— ( <sup>3</sup> / <sub>9</sub> ) . . . . .	6.5	33.01	at Dvergasteinn.
Borgarfjörður ( <sup>4</sup> / <sub>9</sub> ) . . . . .	7.1	34.45	out in the fjord.
Vopnafjörður ( <sup>5</sup> / <sub>9</sub> ) . . . . .	7.5	33.27	near land.

From the most westerly part of the north coast and from the northern part of the north-west coast as also from Breiðifjörður measurements are to hand of the temperature and salinity of the ocean at various depths in the interior of the fjords taken by Bjarni Sæmundsson (Fiskirannsóknir, 1908, Andvari, XXXIV árg.) of which the following are given: —

	Depth in metres	Temp. C°	Salinity ‰
North coast,			
Steingrímsfjörður ( <sup>31</sup> / <sub>7</sub> ) . . . . .	0	10.8	27.4
	15	9.7	
	30	9.2	34.3
	55	3.2	34.5
Steingrímsfjörður ( <sup>2</sup> / <sub>3</sub> ) . . . . .	0	10.6	34.0
	15	9.9	
	35	7.8	34.6
	70	5.8	34.7
	100	4.2	34.7
Hrútafjörður ( <sup>7</sup> / <sub>8</sub> ) . . . . .	0	7.5	34.6
	15	6.0	
	30	4.8	34.7
	44	4.5	35.0
North-west coast,			
Mjóifjörður, the inner part ( <sup>20</sup> / <sub>7</sub> ) . . . . .	0	11.8	30.6
	25	6.5	34.5
	50	3.2	34.9

	Depth in metres	Temp. C°	Salinity ‰
Skötufjörður, the inner part ( <sup>16</sup> / <sub>7</sub> ) . . . . .	0	11.4	30.5
	15	8.9	
	35	7.9	34.3
	70	7.4	34.7
	105	4.6	34.7
Isafjarðardjúp, 1½ mile NW. of Ögur- nes ( <sup>18</sup> / <sub>7</sub> ) . . . . .	0	11.8	32.2
	15	11.5	
	35	8.5	34.0
	70	6.8	34.9
	100	6.6	35.5
South-west coast,			
Skarðsstöð in Breiðifjörður ( <sup>13</sup> / <sub>8</sub> ) . . . . .	0	10.9	34.0
(outside)	8	10.8	34.5
Skarðsstöð . . . . .	0	11.1	24.8
(near land)	6	11.0	34.3

Bjarni Sæmundsson has kindly given me the permission, moreover, to make use of his hitherto unpublished measurements of the temperature of the ocean at SW. Iceland (Breiðifjörður and Faxaflói), in the interior of the fjords, from the summer of 1909. Of these the following are given: —

	Depth in metres	Temp. C°	Salinity ‰
Breiðifjörður			
Stykkishólmur (the port <sup>5</sup> / <sub>7</sub> ) . . . . .	0	10.6	35.1
About ½ a mile SE. of Vaðstakksey ( <sup>7</sup> / <sub>7</sub> )	0	10.1	34.2
	15	10.1	
	30	10.1	34.6
	63	10.0	35.1
About ½ a mile SE. of Hrappsey ( <sup>10</sup> / <sub>7</sub> )	0	11.5	33.9
	15	10.8	
	30	10.7	34.0
	70	10.5	34.2
Kolgrafarfjörður, the interior ( <sup>17</sup> / <sub>7</sub> ) . . . .	0	11.0	33.9
	10	10.6	
	20	10.6	34.2
	35	10.5	34.1
Kolgrafarfjörður, the mouth ( <sup>18</sup> / <sub>7</sub> ) . . . . .	0	9.8	34.7
	15	9.7	34.8
Hvamsfjörður about 2 miles SE. of Lambey ( <sup>10</sup> / <sub>7</sub> ) . . . . .	0	11.4	32.7
	15	11.0	
	30	11.0	33.7
	45	10.9	34.1

	Depth in metres	Temp. C°	Salinity ‰	
Faxaflói				
5 miles SW. of Akranes ( <sup>26</sup> / <sub>7</sub> )	0	11.5	34.4	
	15	10.6		
	30	9.2	34.7	
	60	7.8	34.9	
Knararnes .....	0	14.0	34.0	
About 2 miles SE. of Þor- móðssker ( <sup>31</sup> / <sub>7</sub> ).....	0	12.2	34.6	
	15	10.2		
	30	9.5	34.6	
	45	9.1	34.7	
Borgarnes ( <sup>3</sup> / <sub>8</sub> ).....	0	12.4	26.9	high-water.
— ( <sup>5</sup> / <sub>8</sub> ).....	0	12.4	18.9	low-water.
Within Seleyri .....	0	11.2	8.8	
	5	10.6	14.7	
Borgarfjörður, the mouth ( <sup>7</sup> / <sub>8</sub> )	0	11.7	28.9	
	10	11.6		
	20	11.5	34.4	
Hvalfjörður, Hvammsdjúp ( <sup>13</sup> / <sub>8</sub> ) .....	0	11.6	33.4	
	15	11.4		
	30	11.2	34.0	
	60	11.1	34.2	
Hvalfjörður, Galtarvíkurdjúp	0	11.7	33.9	
	15	11.5		
	30	11.1	34.0	
	50	11.1	34.4	
	85	11.0	34.3	

From the measurements given above it will be seen that the temperature of the water in the interior of the small fjords is nearly the same from surface to bottom, while a regular decrease of warmth is immediately felt with the increase of depth in the more open waters. The temperature of the fjord-water is evidently dependent on the climate of the country; but regarding the temperature, during winter, for instance, we know nothing. Nor am I prepared to treat of the distribution of warmth in the coastal water in a more exact manner, as from the scattered observations made during the summer, which are at our disposal, no satisfactory results can be arrived at regarding the thermal conditions in which the algal vegetation exists all the year round.

### C. The Salinity.

The degree of salinity is given above, together with the temperature.

a. The Sea. South of Iceland the salinity varies but slightly, with the exception of the coastal water itself. During the summer, at any rate, the salinity of the coastal water must be considerably lower on account of the great amount of fresh water brought down by all the rivers of the south. On the other coasts and especially those of N. and E. Iceland the salinity varies according to whether the layers of water originate from currents which are deficient in salt or from the Irminger current, and also with the amount of fresh water streaming out from land. At station 106 (see above) the inferior salinity is evidently due to cold water from the Greenland current, and at station 73 it is probably due to fresh water.

b. The Fjords. The salinity inside the fjords varies considerably and the variation is dependent upon the amount of fresh water which intermingles with the water in the fjord, partly in the form of river water and partly in the form of precipitated moisture. The lowest salinity in the fjords was 1.31 ‰ in Eskifjörður after rain. Heavy rainfalls must be capable of causing such an inferior salinity in other places also, especially in narrow fjords, but this will not last long, and as the littoral algæ can endure heavy showers during low-tide, they will not suffer to any extent worth mentioning.

In places where the salinity is as low as in Seyðisfjörður (9.23 ‰), where a rather large river disembogues, the algal vegetation occurs sparingly, although algæ are found, especially green and brown algæ. At a place like Borgarnes, where the salinity is low (18.9; 26.9) on account of fresh water from Hvítá, the algal vegetation occurs more abundantly than at the very head of Seyðisfjörður by the river, but the inferior salinity excludes certain species, for instance, *Polysiphonia fastigiata*, although *Ascophyllum* occurs abundantly. Further out, where the sea is more saline, it is not absent.

It is especially in the surface-water of the fjords that the salinity varies so much. It is greater in the large open fjords, such as Faxaflói, than in the small land-locked fjords, such as Hvalfjörður, a circumstance which must certainly be due to river-water. The figures given show also that the salinity of the surface-water of the smaller fjords is less in the inner part than in the outer part. The same difference seems to appear also between the deeper layers of water of the inner and outer parts.

As a rule, the salinity of the deeper layers is higher and more stable, which must be beneficial to the vegetation in the depths.



## 3. THE AIR.

The climate is of special importance to that part of the algal vegetation which is exposed during low-tide. The temperature is possibly of least importance in a climate where high and very low degrees of temperature do not occur, or are, at any rate, rare. The degree of humidity of the air and the cloud-covering are, on the other hand, highly important to the algal vegetation which is left dry. The movements of the air are also of importance, especially as it produces movements in the sea.

## A. The Temperature.

The following means (19 years)<sup>1</sup> from a number of stations on different parts of the coast are here given for the elucidation of the thermal conditions.

	Winter	Spring	Summer	Autumn	The year
E. Iceland					
Papey . . . . .	— 1.1	0.1	6.0	3.3	2.1
Berufjörður . . . . .	— 1.4	0.8	7.6	3.5	2.6
N. Iceland					
Raufarhöfn . . . . .	— 4.0	— 1.9	6.5	1.6	0.5
Grímsey . . . . .	— 2.3	— 1.5	6.1	2.9	1.3
SW. Iceland					
Stykkishólmur . . . . .	— 2.2	0.8	8.9	3.9	2.9
S. Iceland					
Vestmannaeyjar . . . . .	1.1	3.8	9.7	5.2	5.0
Eyrbakkí . . . . .	— 2.0	2.1	10.2	3.5	3.5

From the figures given above it will be possible to form an opinion of the thermal conditions in the places mentioned, and these are altogether such that an algal vegetation left dry can thrive everywhere along the coast. The extremes will not have a sufficiently injurious effect on the vegetation for it to be noticeable in the long run. High degrees of temperature, about 20° C for example, occur rarely in the summer, and will have no permanent effect. Very low degrees of temperature in the winter will not injure the vegetation left dry to any extent worth mentioning, as it is then partly protected by snow (at the very top) and partly by ice.

I do not consider the cold in the winter injurious to the vegetation which is left dry, as the algæ certainly endure being frozen fairly well. At least I have seen uppermost in the littoral zone,

<sup>1</sup> Willaume-Jantzen, Meteorologiske Middeltal og Extremer for Færøerne, Island og Grönland. Kjöbenhavn, 1899.

early in May, algæ which had been frozen hard during the night, apparently quite unharmed and alive when thawed, nor could one perceive next day that they had suffered at all; but, as I was travelling, I was not able to observe them more than these two days. It is also a foregone conclusion that the algæ left dry must freeze in the winter when the cold is severe, but it does not appear that they suffer thereby.

If the cold cannot be said to have any directly injurious effect, yet indirectly it may hurt the vegetation (though not to any great extent) by the fact that the water freezes and the beach becomes ice-covered. During severe winters a covering of ice may be found during the greater part of the winter in the smaller fjords, and especially where the fjord-water is abundantly mixed with fresh water, and even if the winters are quite mild, yet from time to time the water next the beach may freeze. In the littoral zone and on rocks which are laid bare during low-tide, the ice forms in accordance with the substratum, and if this is uneven the ice breaks. At high-water the ice-covering is lifted up; the pieces of ice may then freeze together again, and break once more with the next ebb-tide. During spring-tides in particular these movements are rather considerable and the plant-covering may be a good deal damaged thereby: but if one regards the coasts in their entirety these disturbances will prove to be of small importance.

The drift-ice is much more dangerous to the algal vegetation as the icebergs scrape the rocks with which they come in contact. Strömfelt, when travelling in Iceland in 1883, the year following one of the years notable on account of the great quantity of ice, found the littoral vegetation poorly developed in the north country. This most certainly resulted from the drift-ice having blockaded the coast during the whole summer of 1882. In the summer of 1898, I saw on the promontory between Seyðisfjörður and Loðmundarfjörður distinct signs of the drift-ice which had been there in the spring. The injurious influence of the drift-ice consists mainly in the fact that it scrapes away the vegetation from the parts with which it comes in contact; possibly also in the fact that it reduces the temperature to far below normal. That the plants suddenly find themselves in a much colder medium than they are accustomed to must produce a check upon them, particularly on the more sensitive species. The marine plants, however, are less affected by this than the land vegetation. As a rule, ice-years occur at fairly long intervals;

consequently the damage which the ice causes is not noticeable in the long run, it is noticed chiefly in the same year or the year following, and is remedied comparatively quickly.

### B. The Humidity.

Very great importance must be ascribed to this as regards the algal vegetation left exposed. During the period of desiccation there is always the danger of the evaporation becoming too great, especially if the air is dry. The more humid the air, the better the algæ will be able to maintain life in it. The following figures from four places, each situated on a different part of the coast, show the mean humidity of the air as percentages (Willaume-Jantzen l. c.).

	Winter	Spring	Summer	Autumn
E. Icel. Berufjörður (23 years).....	77	78	81	80
N. Icel. Grímsey (21 years) .....	83	83	85	86
SW. Icel. Stykkishólmur (20-23 years) .	88	85	83	86
S. Icel. Vestmannaeyjar (12 years) ....	81	79	82	81

As a comparison with the Færøes might be of interest, the figures showing the mean humidity as percentages at Thorshavn (Willaume-Jantzen, l. c.) are appended.

	Winter	Spring	Summer	Autumn
Thorshavn in the Færøes (25 years)..	81	79	84	84

From these figures it appears that the humidity of the air in Berufjörður is less than in the Færøes while the humidity of the air at Grímsey and also at Stykkishólmur is greater than in the Færøes. The humidity of the air in the winter and the spring in the Vestmannaeyjar and in the Færøes is the same, while at the latter place it is a little greater in the summer and autumn.

### C. Precipitation, Amount of Cloud, Foggy days, Wet days.

a. Precipitation. The following figures show for purposes of comparison the mean downfall in millimetres at four places in Iceland, one on each coast, and at Thorshavn in the Færøes (Willaume-Jantzen, l. c.).

	Winter	Spring	Summer	Autumn	The year
E. Icel. Berufjörður (23 years)...	348.0	222.7	203.7	340.3	1114.7
N. Icel. Grímsey (16-22 years)...	83.5	64.8	85.6	139.9	373.8
SW. Icel. Stykkishólmur (18-22 yrs.)	191.5	115.2	113.6	203.8	624.1
S. Icel. Vestmannaeyjar (15 years) ..	354.1	257.3	252.1	402.2	1265.7
Thorshavn in the Færøes (25 yrs.)	510.9	485.2	272.4	324.6	1593.1

As shown by the figures there is a considerable difference in the amount of precipitated moisture. That of Thorshavn is greatest, next come the Vestmannaeyjar, followed by Berufjörður. The precipitation at Stykkishólmur is not more than half that in the Vestmannaeyjar, and that of Grímsey is not more than a fourth part of that in the Vestmannaeyjar.

b. Mean Amount of Cloud (Willaume-Jantzen, l. c.).  
Scale 0—10.

	Winter	Spring	Summer	Autumn
E. Icel. Berufjörður (23 years).....	6.4	6.6	6.9	6.6
N. Icel. Grímsey (22 years).....	8.5	8.2	7.9	8.5
SW. Icel. Stykkishólmur (22 years)....	7.1	6.4	6.0	6.9
S. Icel. Vestmannaeyjar (18 years).....	6.2	6.1	6.1	6.3
Thorshavn in the Færøes (25 years)..	7.4	7.1	7.7	7.5

The amount of cloud is greatest in Grímsey, and there is no great difference between the remaining three coast-stations in Iceland. In Thorshavn, however, the amount of cloud is considerably greater and consequently this place approximates to Grímsey.

c. Foggy and Wet days. Mean number of Foggy days (Willaume-Jantzen, l. c.).

	Winter	Spring	Summer	Autumn	The year
E. Icel. Berufjörður (23 years).	44.0	52.0	67.0	49.0	212
N. Icel. Grímsey (22 years) ...	2.4	13.0	31.0	7.0	53
SW. Icel. Stykkishólmur (22 years)	1.0	2.6	4.1	1.3	9
S. Icel. Vestmannaeyjar (18 years)	7.0	12.0	21.0	12.0	52
Thorshavn in the Færøes (25 yrs.)	3.0	10.0	29.0	9.0	51

The number of foggy days in Berufjörður is remarkably high, and at Stykkishólmur is extremely low. In Grímsey the number is much lower during the winter months, and higher during the summer months than it is in the Vestmannaeyjar; there are also small differences during spring and autumn. There are only small differences between the Færøes and the Vestmannaeyjar, except in the winter, when the Vestmannaeyjar have twice as many foggy days.

Mean number of Wet days (Willaume-Jantzen, l. c.).

	Winter	Spring	Summer	Autumn	The year
E. Icel. Berufjörður (23 years).	52	43	34	48	177
N. Icel. Grímsey (22 years) ...	40	29	29	45	143
SW. Icel. Stykkishólmur (22 years)	58	47	40	52	197
S. Icel. Vestmannaeyjar (18 years)	64	55	47	59	225
Thorshavn in the Færøes (25 yrs.)	81	66	58	74	279

At all seasons the number of wet days is highest in the Færøes

and in the Vestmannaeyjar, yet considerably higher in the former place. Grimsey has the fewest wet days, and Berufjörður and Stykkishólmur have somewhat similar numbers.

It is in the spring and the summer especially that the desiccation, during the period of exposure, may have an injurious effect in the zone laid bare along the coast. The amount of cloud is of course important, since clouds diminish the danger of desiccation, but the mean figures are not sufficiently elucidatory. Bright sunny days are not propitious to the vegetation left exposed, especially if several such days occur in succession; and if this takes place at neap-tide, the vegetation which is found above *Pelvetia-Fucus spiralis* is in danger. Although the weather in Iceland varies greatly, longer periods which are damp or dry often occur. Clear days are not uncommon in the spring and summer, and periods of even a week or more of bright weather are not rare. On bright sunny days in summer the temperature may rise rather high; I have measured 20° C. on such a day in a pool in the littoral zone, in the plant-covering itself, and the temperature of the air may rise even higher.

The periods of bright and dry weather are certainly of importance as regards the upper limit of growth of the algal vegetation during the summer. The Færøes are probably less favoured by clear weather than Iceland, and the difference in the upper limit of growth of the algal vegetation in Iceland and in the Færøes may possibly be partly explained by this.

#### D. Winds.

The following figures show the annual percentage (Willaume-Jantzen, l.c.) of the winds: —

	Berufjörður	Grimsey	Stykkishólmur	Vestmannaeyjar
N. ....	6	8	3	13
NE. ....	24	18	18	3
E. ....	4	20	20	23
SE. ....	6	16	16	9
S. ....	8	4	11	8
SW. ....	15	5	10	10
W. ....	4	12	7	8
NW. ....	23	7	3	4
Calm ....	10	10	12	22



It happens rather frequently that the winds are stormy and, as an example, the annual percentage of storms for Stykkishólmur (from  $\frac{1}{9}$  1845 to  $\frac{31}{2}$  1892) may be given: — N. 32, NE. 61, E. 13, SE. 17, S. 44, SW. 31, W. 26, NW. 11.

The frequency of "calm" is 10 % at Grímsey and in Berufjörður and the frequency of "wind" is therefore 90 % in both places; at Stykkishólmur the frequency of "calm" is 12 % and that of "wind" 88 %; in the Vestmannaeyjar the frequency of "calm" is 22 % and that of "wind" 78 %.

At Thorshavn, in the Færøes, the annual "calm" is 11 % and the frequency of "wind" 89 %, somewhat the same, therefore, as at Stykkishólmur and greater than in the Vestmannaeyjar.

#### 4. LIGHT.

The influence of light on the distribution of the algal associations and on their appearance is, as is well-known, exceedingly great. Without doubt most investigators assume that the main division of algal vegetation into a green, a brown and a red zone is due to the quality of the light, but one cannot on that account consider the intensity of the light to be of no importance. To what extent the shades of colour in the red algæ are to be regarded as an adaptation to the intensity of the light or to the quality of the light, I find rather difficult to decide.

I agree with Berthold and Oltmanns in thinking that the *Florideæ* may be characterized as shade-plants in the same sense that we speak of shade-vegetation in lava-clefts and in other places where there is a faint light. By shade-plants I understand plants which prefer feebly illuminated spots, and do not, as a rule, thrive in the full light of day. In the tidal region (Part VI) the littoral *Florideæ* evidently prefer crevices and grottoes, i. e. feebly illuminated places, and thus prove themselves to be shade-plants.

I shall not enter more fully into the question of light, as I have made no experiments in that connection and, moreover, the subject requires to be reinvestigated (Oltmanns, 54).

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### III. THE HORIZONTAL DISTRIBUTION OF THE SPECIES AND THE COMPONENTS OF THE ALGAL FLORA.

IN the following list (Table I) of the hitherto known Marine Algæ of Iceland a letter (A, B<sub>1</sub>, B<sub>2</sub>, C, D, E<sub>1</sub>, E<sub>2</sub>) is placed before each species, showing to which plant-geographical group I refer it (cf. Børgesen and Jónsson, 14). A indicates the arctic group, B<sub>1</sub> sub-division 1 of the subarctic group, B<sub>2</sub> sub-division 2 of the subarctic group, C the boreal-arctic group, D the cold-boreal group and E the warm-boreal group. The letter *c* placed after the name of the species indicates that it has been found in all the five coastal districts (E. Icel., N. Icel., NW. Icel., SW. Icel. and S. Icel., see above, p. 5); a (*c*) placed after the name of the species indicates that it probably occurs in all parts of the coast.

Table 1. The Distribution of the Species along the coast.

		E. Icel.	N. Icel.	NW.Icel.	SW.Icel.	S. Icel.
<b>Rhodophyceæ.</b>						
C	<i>Bangia fusco-purpurea</i> ( <i>c</i> ) .....	+	+	..	+	+
C	<i>Porphyra umbilicalis</i> <i>c</i> .....	+	+	+	+	+
B <sub>2</sub>	<i>P. miniata</i> <i>c</i> ....	+	+	+	+	+
D	<i>Porphyropsis coccinea</i> .....	..	..	..	+	+
B <sub>2</sub>	<i>Conchocelis rosea</i> <i>c</i> .....	+	+	+	+	+
C	<i>Chantrya microscopica</i> ( <i>c</i> ) .....	..	+	..	..	..
D	<i>C. Alariæ</i> .....	..	..	..	+	+
C	<i>C. secundata</i> <i>c</i> .....	+	+	+	+	+
B <sub>2</sub>	<i>C. virgatula</i> ( <i>c</i> ) .....	..	..	+	+	..
E <sub>1</sub>	<i>Chondrus crispus</i> .....	..	..	(+)	+	+
D	<i>Gigartina mamillosa</i> ( <i>c</i> ) .....	+	+	..	+	+
C	<i>Ahnfeltia plicata</i> .....	..	(+)	(+)	+	+
B <sub>2</sub>	<i>Phyllophora Brodiaei</i> * <i>interrupta</i> ....	+	..	+	..	..
D	<i>P. membranifolia</i> .....	..	..	..	+	+
B <sub>2</sub>	<i>Actinococcus subcutaneus</i> .....	+	..	+	..	..
A	<i>Ceratocolax Hartzii</i> ...	..	..	+	..	..
D	<i>Cystoclonium purpurascens</i> .....	..	+	+	+	+

Table 1. The Distribution of the Species along the coast (continued).

		E. Icel.	N. Icel.	NW.Icel.	SW.Icel.	S. Icel.
A	<i>Turnerella Pennyi</i> .....	+	+	..	..	..
B <sub>2</sub>	<i>Euthora cristata c</i> .....	+	+	+	+	+
B <sub>1</sub>	<i>Rhodophyllis dichotoma (c)</i> .....	+	+	+	+	..
B <sub>2</sub>	<i>Rhodymenia palmata c</i> .....	+	+	+	+	+
E <sub>1</sub>	<i>Lomentaria clavellosa</i> .....	..	..	..	..	+
D	<i>L. rosea</i> .....	..	..	..	..	+
E <sub>1</sub>	<i>Plocamium coccineum</i> .....	..	..	..	..	+
B <sub>1</sub>	<i>Halosaccion ramentaceum c</i> .....	+	+	+	+	+
D	<i>Delesseria alata</i> .....	..	..	..	+	+
A	<i>D. Baerii * corymbosa</i> .....	?	?	..	..	..
B <sub>2</sub>	<i>D. sinuosa c</i> .....	+	+	+	+	+
D	<i>D. sanguinea</i> .....	(+)	..	..	+	+
E <sub>2</sub>	<i>Bonnemaisonia asparagoides</i> .....	..	..	..	..	?
E <sub>1</sub>	<i>Pterosiphonia parasitica</i> .....	..	..	..	..	+
D	<i>Polysiphonia urceolata c</i> .....	+	+	+	+	+
D	<i>P. fastigiata</i> .....	..	..	+	+	+
A	<i>P. arctica</i> .....	+	+	+	+	..
D	<i>P. nigrescens</i> .....	..	+	..	+	..
B <sub>2</sub>	<i>Rhomela lycopodioides c</i> .....	+	+	+	+	+
B <sub>2</sub>	<i>Odonthalia dentata c</i> .....	+	+	+	+	+
D	<i>Callithamnion Arbuscula</i> .....	..	..	..	+	+
E <sub>1</sub>	<i>C. scopulorum</i> .....	..	..	..	+	+
D	<i>Plumaria elegans</i> .....	..	..	..	+	+
B <sub>2</sub>	<i>Ptilota plumosa</i> .....	..	+	+	+	+
B <sub>1</sub>	<i>P. pectinata</i> .....	+	+	+	+	..
C	<i>Antithamnion Plumula v. boreale (c)</i> .....	+	+	+	+	..
D	<i>A. floccosum (c)</i> .....	+	..	..	+	+
D	<i>Ceramium acanthonotum</i> .....	..	..	..	+	+
D	<i>C. Deslongchampsii</i> .....	..	..	..	+	..
D	<i>C. fruticulosum</i> .....	..	..	..	+	..
D	<i>C. circinnatum</i> .....	..	..	..	+	..
E <sub>1</sub>	<i>C. arborescens</i> .....	..	+	+	+	..
D	<i>C. atlanticum</i> .....	..	..	..	+	+
C	<i>C. rubrum (c)</i> .....	..	+	+	+	+
C	<i>Rhodochorton Rothii c</i> .....	+	+	+	+	+
D	<i>R. repens</i> .....	..	..	..	..	+
D	<i>R. minutum</i> .....	..	..	..	+	..
B <sub>1</sub>	<i>R. penicilliforme (c)</i> .....	+	+	+	+	..
C	<i>R. membranaceum (c)</i> .....	+	+	+	+	..
D	<i>Dumontia filiformis (c)</i> .....	+	..	..	+	+
D	<i>Dilsea edulis</i> .....	..	..	..	+	..
D	<i>Petrocelis Hennedyi</i> .....	..	+	+	+	+
A	<i>Cruoria arctica</i> .....	..	..	..	+	..
E <sub>1</sub>	<i>C. pellita</i> .....	..	..	..	+	+
B <sub>1</sub>	<i>Peyssonellia Rosenvingii</i> .....	+	+	+	+	..
D	<i>Rhododermis parasitica</i> .....	..	..	+	+	+

Table 1. The Distribution of the Species along the coast (continued).

		E. Icel.	N. Icel.	NW.Icel.	SW. Icel.	S. Icel.
B <sub>2</sub>	<i>Lithothamnion glaciale</i> (c).....	+	+	..	+	..
D	<i>L. Unger</i> (c).....	+	+	+	..	..
B <sub>1</sub>	<i>L. tophiforme</i> (c).....	+	+	..	+	+
A	<i>L. flavescens</i> .....	+	..	..	..	..
A	<i>L. foecundum</i> .....	+	+	..	..	..
B <sub>1</sub>	<i>L. læve</i> c.....	+	+	+	+	+
D	<i>L. Lenormandi</i> .....	..	..	..	+	..
D	<i>Phymatolithon polymorphum</i> .....	..	?	..	..	+
B <sub>1</sub>	<i>Clathromorphum compactum</i> c.....	+	+	+	+	+
D	<i>Lithophyllum Crouani</i> .....	..	+	+	..	+
D	<i>Dermatolithon macrocarpum</i> .....	..	..	..	+	+
D	<i>Corallina officinalis</i> .....	..	+	+	+	+
C	<i>Hildenbrandia rosea</i> c.....	+	+	+	+	+
<b>Phæophyceæ.</b>						
B <sub>1</sub>	<i>Lithoderma fatiscens</i> (c).....	+	+	+	+	..
D	<i>Petroderma maculiforme</i> .....	..	+	..	..	..
B <sub>1</sub>	<i>Ralfsia ovata</i> (c).....	..	+	..	+	..
B <sub>2</sub>	<i>R. clavata</i> (c).....	+	+	+	+	..
D	<i>R. verrucosa</i> (c).....	+	+	..	+	..
B <sub>1</sub>	<i>R. deusta</i> (c).....	+	+	..	+	+
D	<i>Myrionema vulgare</i> .....	..	+	..	+	..
D	<i>M. Corunnæ</i> .....	..	..	..	..	+
B <sub>1</sub>	<i>M. globosum</i> (c).....	+	+	+	+	..
D	<i>M. færoëense</i> .....	..	..	..	+	..
B <sub>1</sub>	<i>M. Laminariæ</i> (c).....	..	..	..	+	..
D	<i>Ascocyclus islandicus</i> .....	..	+	..	..	..
D	<i>Microsyphar Polysiphoniæ</i> (c).....	..	..	+	+	..
B <sub>1</sub>	<i>Streblonema æcidioides</i> (c).....	+	+	..	+	..
D	<i>S. Stilophoræ</i> v. <i>cæspitosa</i> c.....	+	+	+	+	+
C	<i>Pylaiella littoralis</i> c.....	+	+	+	+	+
B <sub>2</sub>	<i>Ectocarpus tomentosoides</i> c.....	+	+	+	+	+
D	<i>E. tomentosus</i> .....	..	..	..	+	+
C	<i>E. confervoides</i> c.....	+	+	+	+	+
C	<i>E. siliculosus</i> (c).....	..	+	..	+	..
D	<i>E. penicillatus</i> (c).....	+	+	..	+	..
D	<i>E. fasciculatus</i> .....	..	..	..	+	+
D	<i>E. Hinksii</i> .....	..	..	..	..	+
B <sub>2</sub>	<i>Leptonema fasciculatum</i> v. <i>subcylindrica</i> (c).....	..	+	+	+	..
B <sub>2</sub>	<i>Elachista fucicola</i> c.....	+	+	+	+	+
B <sub>1</sub>	<i>Sphacelaria britannica</i> (c).....	..	+	..	+	+
D	<i>S. radicans</i> (c).....	+	+	..	+	+
D	<i>S. olivacea</i> .....	..	..	+	+	+
B <sub>1</sub>	<i>Chætopteris plumosa</i> (c).....	+	+	+	+	..
A	<i>Omphalophyllum ulvaceum</i> .....	+	..	..	..	..

Table 1. The Distribution of the Species along the coast (continued).

		E. Icel.	N. Icel.	NW. Icel.	SW. Icel.	S. Icel.
B <sub>2</sub>	<i>Punctaria plantaginea</i> (c) .....	+	+	+	..	..
B <sub>2</sub>	<i>Litosiphon filiformis</i> (c) .....	+	+	..	+	+
B <sub>2</sub>	<i>Isthmoplea sphaerophora</i> (c) .....	+	..	+	+	+
B <sub>2</sub>	<i>Stictyosiphon tortilis</i> (c) .....	+	+	+	+	..
B <sub>2</sub>	<i>Phaeostroma pustulosum</i> (c) .....	+	..	+	+	..
C	<i>Scytosiphon Lomentaria</i> c .....	+	+	+	+	+
D	<i>Phyllitis zosterifolia</i> (c) .....	+	..	+	+	+
C	<i>Ph. fascia</i> c .....	+	+	+	+	+
B <sub>1</sub>	<i>Coilodesme bulligera</i> .....	+	..	+	+	..
D	<i>Dictyosiphon Ekmani</i> .....	..	..	..	+	..
D	<i>D. Mesogloia</i> .....	..	+	..	..	..
D	<i>D. Chordaria</i> (c) .....	+	..	..	+	..
A	<i>D. corymbosus</i> .....	..	+	..	..	..
B <sub>2</sub>	<i>D. hippuroides</i> (c) .....	..	+	+	+	+
B <sub>2</sub>	<i>D. foeniculaceus</i> (c) .....	+	+	+	+	+
B <sub>2</sub>	<i>Desmarestia viridis</i> c .....	+	+	+	+	+
B <sub>2</sub>	<i>D. aculeata</i> c .....	+	+	+	+	+
E <sub>1</sub>	<i>D. ligulata</i> .....	..	..	..	..	+
D	<i>Castagnea virescens</i> (c) .....	+	+	..	+	..
E <sub>1</sub>	<i>Leathesia difformis</i> .....	..	+	..	+	..
B <sub>2</sub>	<i>Chordaria flagelliformis</i> c .....	+	+	+	+	+
B <sub>2</sub>	<i>Chorda tomentosa</i> (c) .....	+	+	..	+	..
B <sub>2</sub>	<i>C. Filum</i> (c) .....	+	+	+	+	..
B <sub>1</sub>	<i>Saccorhiza dermatodea</i> (c) .....	+	+	+	+	..
D	<i>Laminaria saccharina</i> c .....	+	+	+	+	+
B <sub>1</sub>	<i>L. færoënsis</i> .....	+	+	..	..	..
A	<i>L. nigripes</i> .....	+	..	..	..	..
B <sub>1</sub>	<i>L. digitata</i> c .....	+	+	+	+	+
D	<i>L. hyperborea</i> c .....	+	+	+	+	+
B <sub>1</sub>	<i>Alaria Pylaii</i> c .....	+	+	+	+	+
D	<i>A. esculenta</i> c .....	+	+	+	+	+
D	<i>Fucus spiralis</i> (c) .....	+	+	..	+	+
B <sub>2</sub>	<i>F. inflatus</i> c .....	+	+	+	+	+
D	<i>F. serratus</i> .....	..	..	..	+	+
C	<i>F. vesiculosus</i> c .....	+	+	+	+	+
D	<i>Pelvetia canaliculata</i> .....	..	..	..	+	+
C	<i>Ascophyllum nodosum</i> c .....	+	+	+	+	+
<b>Chlorophyceæ.</b>						
B <sub>2</sub>	<i>Chlorochytrium Cohnii</i> (c) .....	..	..	..	+	..
B <sub>2</sub>	<i>C. inclusum</i> (c) .....	+	+	+	+	..
B <sub>2</sub>	<i>C. dermatocolax</i> (c) .....	..	+	..	+	..
B <sub>1</sub>	<i>C. Schmitzii</i> (c) .....	..	..	..	+	..
D	<i>Codiolum Petrocelidis</i> .....	..	..	..	+	..
B <sub>2</sub>	<i>C. gregarium</i> (c) .....	+	..	..	..	..
D	<i>C. pusillum</i> (c) .....	..	+	..	..	..

Table 1. The Distribution of the Species along the coast (continued).

		E. Icel.	N. Icel.	NW.Icel.	SW.Icel.	S. Icel.
B <sub>2</sub>	<i>Percursaria perscura</i> (c) .....	..	..	..	+	..
D	<i>Enteromorpha aureola</i> .....	..	+	..	..	..
E <sub>1</sub>	<i>E. Linza</i> .....	..	..	..	+	+
C	<i>E. intestinalis</i> c .....	+	+	+	+	+
C	<i>E. clathrata</i> (c) .....	+	+	..	+	+
A	<i>Monostroma groenlandicum</i> .....	+	+	+	..	..
B <sub>2</sub>	<i>M. Grevillei</i> c .....	+	+	+	+	+
B <sub>1</sub>	<i>M. undulatum</i> c .....	+	+	+	+	+
B <sub>1</sub>	<i>M. fuscum</i> c .....	+	+	+	+	+
C	<i>Ulva lactuca</i> (c) .....	..	+	+	+	+
D	<i>Prasiola polyrrhiza</i> (c) .....	..	..	..	+	+
D	<i>P. furfuracea</i> (c) .....	+	+	..	+	..
D	<i>P. stipitata</i> (c) .....	+	+	..	+	+
B <sub>1</sub>	<i>Ulothrix consociata</i> v. <i>islandica</i> .....	..	+	..	..	..
B <sub>1</sub>	<i>U. subflaccida</i> (c) .....	+	+	..	..	..
B <sub>1</sub>	<i>U. pseudoflacca</i> (c) .....	+	..	..	+	+
B <sub>2</sub>	<i>U. flacca</i> c .....	+	+	+	+	+
B <sub>2</sub>	<i>Pseudendoclonium submarinum</i> (c) .....	+	..	..	..	..
D	<i>Entoderma Wittrockii</i> (c) .....	..	+	..	+	+
B <sub>1</sub>	<i>Acrochaete parasitica</i> (c) .....	..	..	..	+	..
D	<i>A. repens</i> .....	..	..	+	..	..
B <sub>2</sub>	<i>Bolbocoleon piliferum</i> (c) .....	+	+	+	..	..
B <sub>2</sub>	<i>Ulvella fucicola</i> (c) .....	+	+	..	+	+
B <sub>2</sub>	<i>Pringsheimia scutata</i> (c) .....	..	..	+	+	..
D	<i>Ochlochaete ferox</i> (c) .....	..	+	..	..	..
B <sub>2</sub>	<i>Urospora mirabilis</i> c .....	+	+	+	+	+
B <sub>1</sub>	<i>U. Hartzii</i> (c) .....	+	..	..	+	+
B <sub>2</sub>	<i>U. Wormskioldii</i> c .....	+	+	+	+	+
C	<i>Chaetomorpha tortuosa</i> (c) .....	+	+	..	+	..
B <sub>2</sub>	<i>C. Melagonium</i> c .....	+	+	+	+	+
C	<i>Rhizoclonium riparium</i> (c) .....	+	+	..	+	..
B <sub>2</sub>	<i>Spongomorpha vernalis</i> (c) .....	..	..	..	+	..
D	<i>Acrosiphonia albescens</i> c .....	+	+	+	+	+
B <sub>2</sub>	<i>A. incurva</i> c .....	+	+	+	+	+
B <sub>1</sub>	<i>A. hystrix</i> (c) .....	+	+	+	+	..
D	<i>A. flabelliformis</i> .....	..	..	..	..	+
B <sub>1</sub>	<i>A. penicilliformis</i> .....	+	..	..	..	..
B <sub>2</sub>	<i>Cladophora rupestris</i> .....	..	..	+	+	+
B <sub>2</sub>	<i>C. hirta</i> (c) .....	..	..	..	+	+
B <sub>2</sub>	<i>C. sericea</i> (c) .....	..	+	..	+	+
D	<i>C. glaucescens</i> (c) .....	..	..	..	+	..
C	<i>C. gracilis</i> (c) .....	+	+	..	+	..
C	<i>Gomontia polyrrhiza</i> (c) .....	+	+	+	+	..
B <sub>2</sub>	<i>Ostreobium Queketti</i> (c) .....	+	+	+	+	..

Table 1. The Distribution of the Species along the coast (continued).

		E. Icel.	N. Icel.	NW.Icel.	SW.Icel.	S. Icel.
<b>Cyanophyceæ.</b>						
B <sub>2</sub>	<i>Pleurocapsa amethystea</i> c. ....	+	+	+	+	+
D	<i>Plectonema norvegicum</i> (c) .....	..	+	..	..	..
E	<i>Phormidium autumnale</i> (c) .....	+	..	..	..	..
C	<i>Spirulina subsalsa</i> (c) .....	..	+	..	+	..
C	<i>Calothrix scopulorum</i> (c) .....	+	+	..	..	..
C	<i>Rivularia atra</i> (c) .....	..	..	..	+	..

From Iceland (31, 14 and 57) there are published 76 species of red algæ, 67 species of brown, 51 of green and 6 of blue-green — 200 species in all. All of these, of course, are not equally common along the coast, and their habitats, as far as these are known, in the five districts into which the coast is divided, are given in the above table. That table shows that comparatively few species occur in all the coastal districts (in the table, such are indicated by the letter *c* placed after the name of the species). In all parts of the coast are found 15 species (20 %) of red algæ, 18 species (26.8 %) of brown, 10 species (19.6 %) of green and 1 species (16.6 %) of blue-green. Thus, of the 200 species there are 44 species (22 %) which are common to all the coastal districts.

If we take into consideration the fact that the great stretch of coast round the whole of Iceland is as yet far from accurately investigated, we may expect, after future investigations, not only that several more species will be found, but also that the distribution of the species in the different parts of the coast will prove to differ from what is at present stated to be the case. Therefore, in the above list of the distribution of the species along the coast I have placed a (*c*) after the name of those species which, as I surmise, are probably to be found in all parts of the coast. I base this supposition partly on the position of the habitats already known along the coast, and partly on the occurrence of the species in the adjacent floral districts, e. g. the Færøes and Greenland.

The mark (*c*) is subjoined to 14 species of red algæ, 29 species of brown, 32 species of green and to 5 species of blue-green. On adding to this the above-mentioned species which have the letter *c* subjoined we get 29 species (38 %) of red algæ, 47 species (70 %) of brown, 42 species (82 %) of green and 6 species (100 %) of blue-green. Thus, of the 200 species 124 prove to be common to all parts



of the coast. The percentage of each group is of the greatest importance, and for the sake of explicitness I have arranged these figures in a tabular form, both those which refer to  $c$  and those which refer to  $c + (c)$ .

Species common to all the coastal districts, given as percentages.

	Red algæ	Brown algæ	Green algæ	Blue-green algæ	All the groups collectively
$c$ . . . . .	20	27	19	17	22
$c + (c)$ . . . .	38	70	82	100	60

On considering these two series of figures it becomes evident that the figures given for  $c + (c)$  come nearer to the real facts, while those given for  $c$  merely indicate an incomplete knowledge of the coastal distribution of the species. The fact is that, where there is not a greater climatic difference between the different parts of the coast than is the case in Iceland, it may always be expected that, as regards the common species, the highest numbers will fall to the green and to the blue-green algæ; and where the hydrographic differences between the different parts of the coast are as pronounced as they are in Iceland, it is natural that the smallest number will fall to the red algæ, and just as naturally the brown algæ will in this respect be placed almost midway between the red and the green algæ.

Therefore, as regards the floristic difference between the different parts of the coast, particular stress is laid on the remaining 76 species. In the following table they are arranged according to their habitats. Under A, those species are given which either occur in E. or N. Iceland only, or are most common there, and thence are distributed southward along the north-west coast as far as SW. Iceland. Under B are given species which either have been found in S. or SW. Iceland only, or are most common there, and thence have a distribution northward along the north-west coast, many of them having, moreover, an eastward distribution along the north coast.

Table 2. The Distribution of the 76 species not common to all the coastal districts.

A	E. Icel.	N. Icel.	NW. Icel.	SW. Icel.	S. Icel.	E. Icel.	N. Icel.	NW. Icel.	SW. Icel.	S. Icel.	B
						..	..	..	..	+	1. Lomentaria clavelllosa
						..	..	..	..	+	2. L. rosea
1. Lithothamnion flavescens	+	..	..	..	..	..	..	..	..	+	3. Plocamium coccineum

Table 2. The Distribution of the 76 species not common to all the coastal districts (continued).

A	E. Icel.	N. Icel.	NW. Icel.	SW. Icel.	S. Icel.	E. Icel.	N. Icel.	NW. Icel.	SW. Icel.	S. Icel.	B
2. <i>Omphalophyllum ulvaceum</i> .....	+	..	..	..	..	..	..	..	..	?	4. <i>Bonnemaïsonia asparagoides</i>
3. <i>Laminaria nigripes</i> .....	+	..	..	..	..	..	..	..	..	+	5. <i>Pterosiphonia parasitica</i>
4. <i>Acrosiphonia penicilliformis</i> .....	+	..	..	..	..	..	..	..	..	+	6. <i>Rhodochorton repens</i>
5. <i>Delesseria Baerii</i> .....	?	?	..	..	..	..	..	..	..	+	7. <i>Phymatolithon polymorphum</i>
6. <i>Turnerella Pennyi</i> .....	+	+	..	..	..	..	..	..	..	+	8. <i>Myrionema Corunnæ</i>
7. <i>Lithothamnion foecundum</i> .....	+	+	..	..	..	..	..	..	..	+	9. <i>Ectocarpus Hinksii</i>
8. <i>Laminaria færoënsis</i> ..	+	+	..	..	..	..	..	..	..	+	10. <i>Desmarestia ligulata</i>
9. <i>Petroderma maculiforme</i> ..	..	+	..	..	..	..	..	..	..	+	11. <i>Acrosiphonia flabelliformis</i>
10. <i>Ascoecylus islandicus</i> ..	..	+	..	..	..	..	..	..	..	+	12. <i>Porphyropsis coccinea</i>
11. <i>Dictyosiphon Mesogloia</i> ..	..	+	..	..	..	..	..	..	..	+	13. <i>Chantransia Alariæ</i>
12. <i>D. corymbosus</i> .....	..	+	..	..	..	..	..	..	..	+	14. <i>Phyllophora membranifolia</i>
13. <i>Enteromorpha aureola</i> ..	..	+	..	..	..	..	..	..	..	+	15. <i>Delesseria alata</i>
14. <i>Ulothrix consociata</i> v. <i>islandica</i> .....	..	+	..	..	..	..	..	..	..	+	16. <i>Callithamnion Arbuscula</i>
15. <i>Monostroma groenlandicum</i> .....	+	+	+	..	..	..	..	..	..	+	17. <i>C. scopulorum</i>
16. <i>Phyllophora Brodiaei</i> v. <i>interrupta</i> .....	+	..	+	..	..	..	..	..	..	+	18. <i>Plumaria elegans</i>
17. <i>Actinococcus subcutaneus</i> ..	+	..	+	..	..	..	..	..	..	+	19. <i>Ceramium acanthonotum</i>
										+	20. <i>Cruoria pellita</i>
										+	21. <i>Dermatolithon macrocarpum</i>
										+	22. <i>Ectocarpus tomentosus</i>
										+	23. <i>E. fasciculatus</i>
										+	24. <i>Fucus serratus</i>
										+	25. <i>Pelvetia canaliculata</i>
										+	26. <i>Enteromorpha Linza</i>
										+	27. <i>Ceramium Deslongchampsii</i>
										+	28. <i>C. atlanticum</i>
										+	29. <i>C. fruticosum</i>
										+	30. <i>C. circinnatum</i>
										+	31. <i>Rhodochorton minutum</i>
										+	32. <i>Dilsea edulis</i>
										+	33. <i>Lithothamnion Lenormandi</i>
										+	34. <i>Myrionema færoëense</i>
										+	35. <i>Dictyosiphon Ekmani</i>
										+	36. <i>Codiolum Petrocelidis</i>
										+	37. <i>Chondrus crispus</i>
										+	38. <i>Polysiphonia fastigiata</i>
										+	39. <i>Rhododermis parasitica</i>
										+	40. <i>Sphacelaria olivacea</i>
										+	41. <i>Cladophora rupestris</i>
										+	42. <i>Aerochæte repens</i>



With respect to the 6 species (A, 9—14) which have been found only in N. Iceland, it cannot be assumed that they are confined to the north coast, and it is highly probable that they have a much wider distribution on both sides. *Dictyosiphon corymbosus* and *Ulothrix consociata* v. *islandica* must, however, be assumed to belong more closely to E. and N. Iceland.

As regards the 8 species (A, 15—22) which occur so far west or south as NW. Iceland or SW. Iceland, it must be supposed that their absence from N. Iceland (and E. Iceland [*Ceratocolax*, *Cruoria*]) is due merely to insufficient knowledge regarding their distribution. Of these species, those which extend to SW. Iceland have not been found, however, further south than in Breiðifjörður, with the exception of *Peyssonellia* which has been found in Faxaflói near Reykjavík.

Of the species given under A, Nos. 1—8, 12 and 14—23 must consequently be supposed to have an east-northward distribution along the coast of Iceland, while Nos. 9, 11 and 13 must be supposed to have some other principal distribution; one species (10) is endemic in the most western part of the north coast.

Under B, 53 species are recorded. Of these 10 have been found only in S. Iceland, the majority of these in the Vestmannaeyjar only; to these must be added *Bonnemaisonia* (31, p. 141) which I believe to have been found in S. Iceland. That is, 11 species in all, one of which, however, *Rhodochorton repens*, is endemic. 17 species have been found only in S. and SW. Iceland (B, 12—28) and 8 species in SW. Iceland only. Thus, there are in all 36 species which are known from S. and SW. Iceland only. 6 species (B, 37—42) have a more northern distribution, as they have been found in NW. Iceland. Consequently, there are 42 species which are known only from S. and W. Iceland (NW. Iceland included), but of these species there are two, *Cladophora rupestris* and *Codiolum Petrocelidis* which probably have a more northern distribution. 10 species (B, 43—52) which have principally a south-western distribution (the fact that some of them have not been found in NW., SW. and S. Iceland is probably due to insufficient knowledge regarding their distribution) have been found also in N. Iceland. But all these species do not reach eastward along the north coast to the same extent, *Ptilota plumosa* and *Corallina officinalis* have been found furthest east in the eastern part of the north coast; *Lithophyllum Crouani* and *Myrionema vulgare* in Eyjafjörður; *Ahnfeltia* and *Petrocelis* extend to



Skagafjörður; while *Cystoclonium*, *Polysiphonia nigrescens* and *Leathesia* do not extend further than the most western part of the north coast (the small fjords in Húnaflói). Only *Delesseria sanguinea* now remains; strictly speaking, this appears to belong to the south and south-west coast, but has on one occasion been found in E. Iceland, cast up on the shore. It did not appear to have come from a distance, and it probably grows there, though I did not come across it in the dredgings.

Thus all these 53 species have on the whole a southern and western distribution in Iceland.

The above shows that there is a large neutral territory where the species with a south-western and those with a north-eastern distribution meet and intermingle. This boundary area comprises almost the whole of the north coast, the north-west fjords and, to a certain extent, the northern part of the south-west of the country. (For further details see below under the Floristic Boundaries.)

## THE COMPONENTS OF THE ALGAL FLORA.

At present 200 species of Marine Algæ are known from Iceland. In the plant-geographical groups established by Börgesen and myself (Börgesen and Jónsson, 14) these are distributed in the following manner. The definition of the groups is here reproduced almost literally from the publication mentioned.

### A. The Arctic Group.

The species of this group belong to the arctic area of the sea. The southern limit of this area extends from the north and east of Norway southward to the south-east point of Iceland, where the boundary is sharply defined. From E. Iceland the boundary line extends to the north of Iceland between Iceland and Greenland, and then turns considerably southward to the North Atlantic coast of America. The flora of the boreal area of the Atlantic passes without any distinct limit into the arctic algal flora on both sides of the Atlantic. In Iceland the limit is distinct only at the south-east point whereas the boundary is very indistinct on the north-east part of the coast.

Some of the species of this group occur, but only rarely, south of the border-zone.

## Rhodophyceæ.

Ceratocolax Hartzii.	Cruoria arctica.
Turnerella Pennyi.	Lithothamnion flavescens.
Delesseria Baerii * corymbosa.	L. foecundum.
Polysiphonia arctica.	

## Phæophyceæ.

Omphalophyllum ulvaceum.	Laminaria nigripes.
Dictyosiphon corymbosus.	

## Chlorophyceæ.

Monostroma groenlandicum.
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**B. The Subarctic Group.**

## Subdivision I.

The species of this subdivision are common in the Arctic Sea, and are rather common in the cold-boreal area of the Atlantic Ocean as far south as the Færøes and Nordland; some of them occur, although rarely, as far south as England.

## Rhodophyceæ.

Rhodophyllis dichotoma.	Peyssonellia Rosenvingii.
Halosaccion ramentaceum.	Lithothamnion tophiforme.
Ptilota pectinata.	L. læve.
Rhodochorton penicilliforme.	Clathromorphum compactum.

## Phæophyceæ.

Lithoderma fatiscens.	Chætopteris plumosa.
Ralfsia ovata.	Coilodesme bulligera.
R. deusta.	Saccorrhiza dermatodea.
Myrionema globosum.	Laminaria færøensis.
M. Laminariæ.	L. digitata.
Streblonema æcidioides.	Alaria Pylaii.
Sphacelaria britannica.	

## Chlorophyceæ.

Chlorochytrium Schmitzii.	U. pseudoflacca.
Monostroma undulatum.	Acrochæte parasitica.
M. fuscum.	Urospora Hartzii.
Ulothrix consociata v. islandica.	Acrosiphonia hystrix.
U. subflaccida.	A. penicilliforme.

## Subdivision II.

This subdivision includes species, which are either common in the Arctic Sea and the North Atlantic from western France—England northward, or which, if not common, are at least all equally frequent.



## Rhodophyceæ.

<i>Porphyra miniata.</i>	<i>Rhodymenia palmata.</i>
<i>Conchocelis rosea.</i>	<i>Delesseria sinuosa.</i>
<i>Chantransia virgatula.</i>	<i>Rhodomela lycopodioides.</i>
<i>Phyllophora Brodiaei</i> * <i>interrupta.</i>	<i>Odonthalia dentata.</i>
<i>Actinococcus subcutaneus.</i>	<i>Ptilota plumosa.</i>
<i>Euthora cristata.</i>	<i>Lithothamnion glaciale.</i>

## Phæophyceæ.

<i>Ralfsia clavata.</i>	<i>Phæostroma pustulosum.</i>
<i>Ectocarpus tomentosoides.</i>	<i>Dictyosiphon hippuroides.</i>
<i>Leptonema fasciculatum</i> v. <i>subcylindrica.</i>	<i>D. foeniculaceus.</i>
<i>Elachista fucicola.</i>	<i>Desmarestia viridis.</i>
<i>Punctaria plantaginea.</i>	<i>D. aculeata.</i>
<i>Litosiphon filiformis.</i>	<i>Chordaria flagelliformis.</i>
<i>Isthmoplea sphærophora.</i>	<i>Chorda tomentosa.</i>
<i>Stictyosiphon tortilis.</i>	<i>C. filum.</i>
	<i>Fucus inflatus.</i>

## Chlorophyceæ.

<i>Chlorochytrium Cohnii.</i>	<i>Pringsheimia scutata.</i>
<i>C. inclusum.</i>	<i>Urospora mirabilis.</i>
<i>C. dermatocolax.</i>	<i>U. Wormskioldii.</i>
<i>Codiolum gregarium.</i>	<i>Chætomorpha Melagonium.</i>
<i>Percursaria percura.</i>	<i>Spongomorpha vernalis.</i>
<i>Monostroma Grevillei.</i>	<i>Acrosiphonia incurva.</i>
<i>Ulothrix flacca.</i>	<i>Cladophora rupestris.</i>
<i>Pseudendoclonium submarinum.</i>	<i>C. hirta.</i>
<i>Bolbocoleon piliferum.</i>	<i>C. sericea.</i>
<i>Ulvella fucicola.</i>	<i>Ostreobium Queketti.</i>

## Cyanophyceæ.

*Pleurocapsa amethystea.*

**C. The Boreal-Arctic Group.**

The species of this group are common in the Arctic Sea and the boreal area of the Atlantic at least as far south as the Atlantic coast of North Africa; probably some of them have a far greater southern distribution. Some of them might possibly be considered cosmopolitan.

## Rhodophyceæ.

<i>Bangia fuscopurpurea.</i>	<i>Antilhamnion Plumula</i> v. <i>boreale.</i>
<i>Porphyra umbilicalis.</i>	<i>Ceramium rubrum.</i>
<i>Chantransia microscopica.</i>	<i>Rhodochorton Rothii.</i>
<i>C. secundata.</i>	<i>R. membranaceum.</i>
<i>Ahnfeltia plicata.</i>	<i>Hildenbrandia rosea.</i>

## Phæophyceæ.

<i>Pylaiella littoralis</i> .	<i>Phyllitis fascia</i> .
<i>Ectocarpus confervoides</i> .	<i>Fucus vesiculosus</i> .
<i>E. siliculosus</i> .	<i>Ascophyllum nodosum</i> .
<i>Scytosiphon Lomentaria</i> .	

## Chlorophyceæ.

<i>Enteromorpha intestinalis</i> .	<i>Rhizoclonium riparium</i> .
<i>E. clathrata</i> .	<i>Cladophora gracilis</i> .
<i>Ulva lactuca</i> .	<i>Gomontia polyrrhiza</i> .
<i>Chætomorpha tortuosa</i> .	

## Cyanophyceæ.

<i>Spirulina subsalsa</i> .	<i>Rivularia atra</i> .
<i>Calothrix scopulorum</i> .	

**D. The Cold-Boreal Group.**

The species of this group have their area of distribution from western France—England northward to S. Iceland, the Færøes and Nordland—Finmark. Some few species have occasionally been found in the Arctic Sea, especially in the White Sea and the Murman Sea, and some few reach as far south as the Mediterranean and North Africa.

## Rhodophyceæ.

<i>Porphyropsis coccinea</i> .	<i>Ceramium fruticulosum</i> .
<i>Chantransia Alariæ</i> .	<i>C. circinnatum</i> .
<i>Gigartina mamillosa</i> .	<i>C. atlanticum</i> .
<i>Phyllophora membranifolia</i> .	<i>Rhodochorton repens</i> .
<i>Cystoclonium purpurascens</i> .	<i>R. minutum</i> .
<i>Lomentaria rosea</i> .	<i>Dumontia filiformis</i> .
<i>Delesseria alata</i> .	<i>Dilsea edulis</i> .
<i>D. sanguinea</i> .	<i>Petrocelis Hennedyi</i> .
<i>Polysiphonia urceolata</i> .	<i>Rhododermis parasitica</i> .
<i>P. fastigiata</i> .	<i>Lithothamnion Ungerii</i> .
<i>P. nigrescens</i> .	<i>L. Lenormandi</i> .
<i>Callithamnion Arbuscula</i> .	<i>Phymatolithon polymorphum</i> .
<i>Plumaria elegans</i> .	<i>Lithophyllum Crouani</i> .
<i>Antithamnion floccosum</i> .	<i>Dermatolithon macrocarpum</i> .
<i>Ceramium acanthonotum</i> .	<i>Corallina officinalis</i> .
<i>C. Deslongchampsii</i> .	

## Phæophyceæ.

<i>Petroderma maculiforme</i> .	<i>Ascocyclus islandicus</i> .
<i>Ralfsia verrucosa</i> .	<i>Microsiphia Polysiphoniæ</i> .
<i>Myrionema vulgare</i> .	<i>Streblonema Stilophoræ v. cæspitosa</i> .
<i>M. Corunnæ</i> .	<i>Ectocarpus tomentosus</i> .
<i>M. færøense</i> .	<i>E. penicillatus</i> .

*Ectocarpus fasciculatus*.  
*E. Hinksiae*.  
*Sphacelaria radicans*.  
*S. olivacea*.  
*Phyllitis zosterifolia*.  
*Dictyosiphon Ekmani*.  
*D. Mesogloia*.  
*D. Chordaria*.

*Castagnea virescens*.  
*Laminaria saccharina*.  
*L. hyperborea*.  
*Fucus spiralis*.  
*F. serratus*.  
*Pelvetia canaliculata*.  
*Alaria esculenta*.

#### Chlorophyceæ.

*Codiolum Petrocelidis*.  
*C. pusillum*.  
*Enteromorpha aureola*.  
*Prasiola polyrrhiza*.  
*P. furfuracea*.  
*P. stipitata*.

*Entoderma Wittrockii*.  
*Acrochaete repens*.  
*Ochlochaete ferox*.  
*Acrosiphonia albescens*.  
*A. flabelliformis*.  
*Cladophora glaucescens*.

#### Cyanophyceæ.

*Plectonema norvegicum*.

### E. The Warm-Boreal Group.

The majority of the species referred to this group extend at least as far south as the Mediterranean and the Atlantic coast of North Africa. According to the different distribution northward the group is divided into three parts of which only the one reaches as far north as S. Iceland.

1. Species extending as far north as S. Iceland, the Færøes and Northern Norway, and at least as far south as the Mediterranean and North Africa.

#### Rhodophyceæ.

*Chondrus crispus*.  
*Lomentaria clavellosa*.  
*Plocamium coccineum*.  
*Bonnemaisonia asparagoides*.  
*Pterosiphonia parasitica*.

*Callithamnion scopulorum*.  
*Ceramium arborescens*.  
*Cruoria pellita*.

#### Phæophyceæ.

*Desmarestia ligulata*.

*Leathesia difformis*.

#### Chlorophyceæ.

*Enteromorpha Linza*.

#### Cyanophyceæ.

*Phormidium autumnale*.

According to the above the number of species in the groups is as follows: —

	Rhodo- phyceæ	Phæo- phyceæ	Chloro- phyceæ	Cyano- phyceæ		
1. The arctic group.....	7	3	1	»	= 11 species	(5.5 <sup>0</sup> /o)
2. The subarctic group:						
Subdivision I.....	8	13	10	»	= 31 —	(15.5 <sup>0</sup> /o)
3. The subarctic group:						
Subdivision II.....	12	17	20	1	= 50 —	(25.0 <sup>0</sup> /o)
4. The boreal-arctic group	10	7	7	3	= 27 —	(13.5 <sup>0</sup> /o)
5. The cold-boreal group.	31	25	12	1	= 69 —	(34.5 <sup>0</sup> /o)
6. The warm-boreal group	8	2	1	1	= 12 —	(6.0 <sup>0</sup> /o)
	76	67	51	6		

If we divide the six groups into two parts, A: the first three groups, and B: the last three<sup>1</sup> groups, we obtain the following figures: —

A, 92 species (46 %/o) and B, 108 species (54 %/o).

The floral district must therefore be determined as boreal, because more than half of the species belong to the last three groups. Of these groups the cold-boreal is the most important because its species form 64 %/o of the total number of species (108) in all three groups. This floral district has not, however, a purely boreal character, as the subarctic group is rich in species and gives a rather high percentage (41 %/o). The floral district, then, is characterized to a very high degree by a boreal element, and next by a subarctic element.

If we consider only the red and the brown algæ, 143 species in all, the cold-boreal character is a little more strongly pronounced than the subarctic. The figures are: — Arctic 10 species (7 %/o), subarctic 50 species (35 %/o), boreal-arctic 17 species (12 %/o), cold-boreal 56 species (39 %/o) and warm-boreal 10 species (7 %/o). The first three groups have 60 species (42 %/o), the last three 78 species (58 %/o).

If we compare the five divisions of the coast with respect to the number of species in the different groups, we obtain the figures given in Tables 3, 4.

If, for instance, we select the red and the brown algæ (Table 4) as a basis, then the difference which exists in the different parts of the coast is very evident. In E. Iceland the arctic group contains the greatest number of species, and this number — if we follow the divisions of the coast in the order of the tables — decreases

<sup>1</sup> The boreal-arctic group is included in the boreal groups, as its species, though common in the arctic district, have a far larger area of distribution outside this.

**Table 3. Red algæ, Brown algæ, Green algæ, Blue-green algæ collectively.**

	E. Icel.		N. Icel.		NW. Icel.		SW. Icel.		S. Icel.	
	Number of species	0/0	Number of species	0/0	Number of species	0/0	Number of species	0/0	Number of species	0/0
Arctic group.....	8	7	5	4	3	3	2	1	»	»
Subarctic group I.....	25	22	24	20	16	17	27	18	12	11
Subarctic group II.....	38	34	37	30	39	41	44	28	28	26
Boreal arctic group....	20	18	26	21	16	17	23	15	16	15
Cold-boreal group.....	20	18	29	24	18	20	53	34	43	39
Warm-boreal group....	1	c. 1	2	c. 1	2	c. 2	6	4	9	9
Total...	112		123		94		155		108	

**Table 4. Red and Brown algæ collectively.**

	E. Icel.		N. Icel.		NW. Icel.		SW. Icel.		S. Icel.	
	Number of species	0/0	Number of species	0/0	Number of species	0/0	Number of species	0/0	Number of species	0/0
Arctic group.....	7	9	4	5	2	3	2	2	»	»
Subarctic group I.....	18	23	19	22	13	18	20	17	8	10
Subarctic group II.....	25	31	24	28	27	37	26	23	17	20
Boreal arctic group....	13	16	17	19	13	18	16	14	13	15
Cold-boreal group.....	17	21	21	24	16	22	46	40	38	45
Warm-boreal group....	»	»	2	2	2	2	5	4	8	10
Total...	80		87		73		115		84	

uniformly in the other parts of the coast, and is reduced to 0 in S. Iceland. In E., N., NW. and SW. Iceland the number of the species in the subarctic group I is practically identical in proportion to the number of species, taken as a whole, in these parts of the coast; S. Iceland has a distinctly smaller number, only 10 0/0. The subarctic group II is represented most abundantly in NW. Iceland; E. and N. Iceland come next; but S. and SW. Iceland have a considerably lower percentage (about 20 0/0). The percentage in the boreal-arctic group is practically identical in all parts of the coast. The cold-boreal group presents almost the same percentage in E., N. and NW. Iceland, while the percentage in the group in

SW. and S. Iceland is almost double this. The warm-boreal group is not represented in E. Iceland, and only with extreme rarity (1 species) in N. and NW. Iceland. SW. Iceland has only 4 species, while S. Iceland has 8 (10 %).

There is a very great similarity between S. Iceland and SW. Iceland, if the arctic group in SW. Iceland is excluded; on the other hand, the difference is greatest between E. Iceland and S. Iceland, as is shown by the following figures: —

	East Iceland	South Iceland
Arctic group.....	9 %	0 %
Subarctic groups.....	54 %	30 %
Boreal-arctic group.....	16 %	15 %
Cold-boreal group.....	21 %	45 %
Warm-boreal group.....	0 %	10 %

If we assume that the species marked (c) (Table 1) are to be considered as common to all parts of the coast (see above), the distribution of the 76 not-common species becomes decisive with reference to the floristic difference between the parts of the coast. In the following table, therefore, it is shown how these 76 species are arranged in the six plant-geographical groups of algæ.

**Table 5. Group-division of the 76 not-common species** (see Table 2).

A	E. Icel.	N. Icel.	NW Icel.	SW. Icel.	S. Icel.	B
Arctic group.....	8	5	3	2	..	Arctic group.
Subarctic group I....	5	4	3	3	..	Subarctic group I.
Subarctic group II....	2	1	2	2	2	Subarctic group II.
Boreal-arctic group...	1	6	8	31	28	Boreal-arctic group.
Cold-boreal group....	..	4	..	..	..	Cold-boreal group.
Warm-boreal group...	..	2	2	6	9	Warm-boreal group.
Total number of species	15	9 + 4	8	5	..	Total number of species
	16	23	21	45	40	

The figures in this table show what has been already shown by those which I have given in Tables 3 and 4; but the arctic



element in E. Iceland and the boreal element in S. and SW. Iceland are much more sharply defined; and this is natural, as the species assumed to be common are omitted. Even if we consider only the known distribution of the species, in its entirety (see Table 1), the distribution of the here-mentioned 76 species will still be the most essential reason for the floristic difference between the parts of the coast.

The species assumed to be common are 124 (see above). Of these none are arctic, 25 belong to the subarctic group I, 46 to the subarctic group II, 26 are boreal-arctic, 26 cold-boreal, and one (*Phormidium autumnale*) is warm-boreal. Of the 76 not-common species, 11 are arctic, 6 belong to the subarctic group I, 4 to the subarctic group II, one (*Ahnfeltia plicata*) is boreal-arctic, 43 are cold-boreal and 11 warm-boreal. If we add together the numbers representing the species of the corresponding groups as regards the 124 species assumed to be common and the 76 not-common species (Table 5), and compare with Table 3, we find that the species are more numerous in each district, but that the percentages are almost the same.

If the groups are divided in two parts, A and B (see above) so that A includes the arctic and subarctic groups, and B the three other groups, the following figures are obtained (see Table 4): —

	E. Icel.	N. Icel.	NW. Icel.	SW. Icel.	S. Icel.
A . . . .	50 (63 <sup>0</sup> / <sub>0</sub> )	47 (54 <sup>0</sup> / <sub>0</sub> )	42 (58 <sup>0</sup> / <sub>0</sub> )	48 (42 <sup>0</sup> / <sub>0</sub> )	25 (30 <sup>0</sup> / <sub>0</sub> )
B . . . .	30 (37 <sup>0</sup> / <sub>0</sub> )	40 (46 <sup>0</sup> / <sub>0</sub> )	31 (42 <sup>0</sup> / <sub>0</sub> )	67 (58 <sup>0</sup> / <sub>0</sub> )	59 (70 <sup>0</sup> / <sub>0</sub> )

The arctic group is poorly represented in all the districts of the coast (see Table 4) and therefore the figures mentioned above under A apply chiefly to the subarctic group; the floral districts of E. Iceland, N. Iceland and NW. Iceland are thus subarctic. E. Iceland is subarctic to a greater extent than N. and NW. Iceland. SW. Iceland is a boreal floral district with a very considerable subarctic element, and thus resembles the coasts of Iceland taken as a whole (see above). S. Iceland is a boreal district with a slightly subarctic element.

### Floristic Boundaries.

The mixed character of the flora in N. and NW. Iceland has been alluded to several times in the foregoing pages, and is clearly seen from the tables given, as, for example, Tables 2 and 5. Here,

neither, is any distinct boundary found between the boreal and subarctic floral districts, and the north and north-west of the country must, strictly speaking, be considered a large boundary-area, a view which accords well, also, with the hydrographic conditions. Here, the boreal, subarctic and arctic species intermingle.

At the south-eastern point of Iceland there is, on the other hand, a rather distinct hydrographic boundary along the stretch from Vestrahorn to Eystrahorn (or Lónsheiði). The greater part of this coast is sandy, and difficult of access for the investigation of the algal vegetation. From my own observations I can only say that Berufjörður, the most southerly point in E. Iceland which I have examined with regard to its algal vegetation, has a cold-water flora, and that the Vestmannaeyjar, the most easterly locality on the south coast which I have examined for the same purpose, have a warm-water flora. The boundary must lie between them, and I conclude, especially from the hydrographic conditions and the distribution of the Plankton-associations, that it is situated just on the stretch of coast already mentioned. Ove Paulsen (55 and 56) has given valuable information respecting this boundary, and it is evident from his investigations that the boundary varies to a slight extent, the facts being that in May-June it has been found in the vicinity of Eystrahorn (see 55, map I), but in July-August at Vestrahorn (see 55, map II). If algæ grow on this stretch of coast, one may conclude that there exists a mixed flora resembling that of N. and NW. Iceland. Whether boreal species can be carried to E. Iceland in this manner is at present not easy to say with certainty, yet it seems to me that the occurrence of *Dumontia filiformis* and *Delesseria sanguinea*, both of which are absent in N. and NW. Iceland, can be most easily explained in this way.

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#### IV. COMPARISON WITH NEIGHBOURING FLORAL DISTRICTS.

IN Table 6<sup>1</sup> is given a survey of the plant-geographical distribution of red and brown algæ collectively, in certain subarctic and boreal floral districts. These are so arranged that those floras with the largest arctic element stand furthest to the left. The arctic and subarctic percentages decrease while the boreal percentage increases to the right. The boreal-arctic group is practically similar everywhere, which is also natural according to the geographical distribution of the group. The warm-boreal group is not represented in the subarctic floras, and the arctic group is quite infinitesimal in SW. Iceland and Nordland, and is entirely absent from S. Iceland and the Færøes. In regard to species, the cold-boreal group is extremely poor in East Greenland and Spitzbergen, somewhat richer in West Greenland and considerably richer in E. Iceland.

By grouping the species, as is done above (cf. Börgesen and Jónsson, 14), the character of the floral districts can be determined according to those groups which are richest in species. Thus, I characterize a group as subarctic when more than half of its species are reckoned to the subarctic group. In a similar manner a district is boreal when more than half of its species belong to the boreal groups (bor. arct., cold-bor., and warm-bor.).

Similarly, in an arctic district the species belonging to the arctic group must constitute more than half of the number of species belonging to the district, and, in addition to the subarctic group, only the boreal-arctic will be represented. Of the floral districts mentioned by Börgesen and Jónsson (14) none are arctic according

<sup>1</sup> With the exception of Iceland the numbers of the species of red and brown algæ are taken from Börgesen and Jónsson l. c. (14, p. 22). In regard to East Greenland the numbers are corrected according to Rosenvinge (64), and to West Greenland two species have been added: *Ectocarpus maritimus* and *Chantransia collopoda*.

to the definition here employed. The Siberian Sea, however, comes nearest to it. From here 23 species are known (14), of which 9 (39 %) are arctic, 11 (48 %) subarctic and 3 (13 %) boreal-arctic. This district is at the boundary between arctic and subarctic. Regarded superficially it may appear strange that none of the districts are arctic, but on closer inspection this is easily understood, the reason being that some of the districts (14) are too large and consequently acquire a mixed character. In this respect I shall merely point out, for instance, that both Spitzbergen and East Greenland (and probably West Greenland) ought to be divided into two districts.

As already mentioned, none of the districts recorded in Table 6 is arctic. East Greenland, Spitzbergen and West Greenland have almost the same percentage as regards the arctic species (Table 6), and as this percentage is rather high in proportion to that of the boreal species, these districts could be termed arctic-subarctic, in contradistinction to E. Iceland where the arctic percentage is four times less than the percentage of the boreal species. The boreal districts recorded here (Table 6, p. 70) should, strictly speaking, be called cold-boreal.

If we call the first three groups (in Table 6) A and the three last B the percentages will be as follows: —

	E. Greenl.	Spitzb.	W.Greenl.	* E. Icel.	Finm.	SW. Icel.	S. Icel.	Fær.	Nordl.
A.....	81	77	72	63	46	42	30	29	27
B.....	19	23	28	37	54	58	70	71	73

As the table shows, SW. Iceland agrees most closely with Finmark, while S. Iceland and the Færøes are nearly alike, as Børgesen (12, p. 804) also supposes.

If we take Iceland as a whole, we get 143 species (red and brown algæ collectively), 10 (7 %) arctic, 21 (15 %) subarctic (subdivision I), 29 (20 %) subarctic (subdivision II), 17 (12 %) boreal-arctic, 56 (39 %) cold-boreal and 10 (7 %) warm-boreal. These figures are almost the same as those given for Finmark (see Table 6) and differ, essentially from the figures given for SW. Iceland, only by the higher percentage of arctic and warm-boreal species. If, on the other hand, we take the first three groups collectively and the three last groups in a similar manner, we obtain the same percentages as for SW. Iceland. On combining different parts of the coast, as for instance, E. Iceland and N. Iceland, we get almost the

Table 6. Distribution in groups of Red and Brown algae collectively in certain Subarctic and Boreal floral districts.

	East Greenland.		Spitz-bergen		West Greenland. <sup>1</sup>		E. Iceland.		Finmark		SW. Iceland.		S. Iceland.		Færøes <sup>1</sup>		Nordland	
	Number of species	%	Number of species	%	Number of species	%	Number of species	%	Number of species	%	Number of species	%	Number of species	%	Number of species	%	Number of species	%
Arctic group.....	15	18	10	17	20	18	7	9	7	6	2	2	..	..	..	..	1	1
Subarctic group I.....	26	30	14	23	27	26	18	23	21	17	20	17	8	10	14	9	12	10
Subarctic group II.....	28	33	22	37	31	28	25	31	29	23	26	23	17	20	31	20	20	16
Subarctic group I + II....	54	63	36	60	58	54	43	54	50	40	46	40	25	30	45	29	32	26
Boreal-arctic group.....	12	14	9	15	17	16	13	16	18	14	16	14	13	15	17	11	16	13
Cold-boreal group.....	4	5	5	8	13	12	17	21	45	36	46	40	38	45	75	47	61	49
Warm-boreal group.....	..	..	..	..	..	..	..	..	5	4	5	4	8	10	20	13	13	11
Total...	85		60		108		80		125		115		84		157		123	
Subarctic																		
Boreal																		

<sup>1</sup> According to Petersen (57) 2 species of *Ceramium* (*C. Arschougii* [assigned to the subarctic group II] and *C. septentrionale* [assigned to the arctic group]) have here been added to West Greenland. To the Færøes have been added *Ceramium Boergesenii* and *Ceramium atlanticum*, both of which I assign to the cold-boreal group.



same figures as for E. Iceland, and on combining NW., SW. and S. Iceland we get almost the same figures as for SW. Iceland. E. Iceland and N. Iceland have 101 species of red and brown algæ collectively. Of these 8 (8 %) are arctic, 20 (20 %) subarctic (subdivision I), 28 (27 %) subarctic (subdivision II), 17 (17 %) boreal-arctic, 26 (26 %) cold-boreal and 2 (2 %) warm-boreal. NW., SW. and S. Iceland have 131 species of red and brown algæ collectively. Of these 3 (2 %) are arctic, 20 (15 %) subarctic (subdivision I), 29 (22 %) subarctic (subdivision II), 16 (12 %) boreal-arctic, 53 (41 %) cold-boreal and 10 (8 %) warm-boreal.

As regards the components of the flora, both Iceland taken as a whole, and SW. Iceland resemble Finmark; S. Iceland resembles the Færøes and Nordland, and E. Iceland resembles the White Sea.<sup>1</sup>

It is evidently not due to chance that the resemblance of the floral districts happens thus. The situation of Iceland just south of and at the boundary between the arctic and the cold-boreal districts corresponds exactly with the situation of Nordland—Finmark—White Sea in relation to this boundary. Iceland and the White Sea are at the boundary itself, and in Finmark it certainly will be possible to distinguish parts of the coast with a similar mixed flora as in N. and NW. Iceland; the southern part of Finmark will then be something like SW. Iceland, while S. Iceland, as already mentioned, corresponds with Nordland.

This comparison shows only the relation between the quantity of the species of the floral districts within the different groups, but gives no information as to how far the species are common to all those districts. Then it remains to be investigated how many species Iceland has in common with the other districts. At the present time a comparison of the floras will, however, scarcely give any satisfactory results, because all the districts in question are not equally well-known. By future investigations a greater number of species will unquestionably be found in the majority of the floral districts, and the quantity of the species will thus be altered, but the relation between the number of the species of the different groups will, however, undoubtedly remain unaltered.

<sup>1</sup> According to Børgesen and Jónsson (14) 52 species are known from the White Sea, of which 3 (6 %) are arctic, 10 (19 %) subarctic (subdivision I), 19 (37 %) subarctic (subdivision II), 8 (15 %) boreal-arctic and 12 (23 %) cold-boreal. The subarctic species constitute 56 % of the entire number of species and the character of the flora is consequently subarctic in the same degree as that of E. Iceland.



If we compare S. Iceland and the Færøes with regard to common species, the following figures are obtained: —

South Iceland 84 species <sup>1</sup>		The Færøes 157 species
not common	common	not common
10 (6 0/0)	74 (44 0/0)	83 (50 0/0)

Here it should be noted that S. Iceland is so very little known that one is scarcely justified in comparing it with such a well investigated district as the Færøes. Many of the species which in this respect are peculiar to the Færøes will certainly be found in S. Iceland and, at any rate, 32 of them are known from other parts of Iceland, principally from SW. Iceland.

If we choose a larger district of the coast of Iceland, for instance, the boreal district (S. Iceland and SW. Iceland) for comparison with the Færøes, the following figures will be obtained: —

S. and SW. Iceland 126 species		The Færøes 157 species
not common	common	not common
25 (14 0/0)	101 (55 0/0)	56 (31 0/0)

On comparing Iceland with the Færøes we obtain the following figures: —

Iceland 143 species		The Færøes 157 species
not common	common	not common
37 (19 0/0)	106 (55 0/0)	51 (26 0/0)

The 37 species which grow in Iceland and are absent from the Færøes are the following: —

† <i>Chantransia</i> <i>microscopica</i> .	† <i>Petrocelis</i> <i>Hennedyi</i> .
<i>Ceratocolax</i> <i>Hartzii</i> .	<i>Cruoria</i> <i>arctica</i> .
<i>Turnerella</i> <i>Pennyi</i> .	† <i>Peyssonellia</i> <i>Rosenvingii</i> .
<i>Delesseria</i> <i>Baerii</i> .	† <i>Rhododermis</i> <i>parasitica</i> .
<i>Bonnemaïsonia</i> <i>asparagoides</i> . <sup>2</sup>	<i>Lithothamnion</i> <i>flavescens</i> .
<i>Polysiphonia</i> <i>arctica</i> .	<i>L. foecundum</i> .
<i>Ceramium</i> <i>Deslongchampi</i> .	† <i>L. tophiforme</i> .
<i>C. fruticulosum</i> .	† <i>L. Unger</i> i.
<i>C. circinnatum</i> .	† <i>Ralfsia</i> <i>ovata</i> .
<i>C. arborescens</i> .	<i>R. deusta</i> .
† <i>Rhodochorton</i> <i>minutum</i> .	† <i>Myrionema</i> <i>Laminariæ</i>
† <i>R. repens</i> .	† <i>Ascocyclus</i> <i>islandicus</i> .
† <i>Dilsea</i> <i>edulis</i> .	† <i>Ectocarpus</i> <i>penicillatus</i> .

<sup>1</sup> These and the following figures apply to red and brown algae collectively.

<sup>2</sup> I attach no importance to the fact of this species having occurred in Iceland, as it has not yet been found again.

- |                                   |                                   |
|-----------------------------------|-----------------------------------|
| † <i>Sphacelaria radicans</i> .   | † <i>Dictyosiphon Chordaria</i> . |
| † <i>S. olivacea</i> .            | <i>D. corymbosus</i> .            |
| <i>Omphalophyllum ulvaceum</i> .  | <i>Saccorrhiza dermatodea</i> .   |
| † <i>Phæostroma pustulosum</i> .  | <i>Laminaria nigripes</i> .       |
| <i>Coilodesme bulligera</i> .     | † <i>Fucus serratus</i> .         |
| † <i>Dictyosiphon Mesogloia</i> . |                                   |

Which of these species may be found in the Færøes is not easy to decide (cf. also Børgesen, 12, p. 795). But it does not appear altogether improbable that 19 species (marked with a † before the name) could occur there.

The 51 Færøese species which are not found in Iceland are the following: —

- |                                      |                                   |
|--------------------------------------|-----------------------------------|
| † <i>Erythrotrichia ceramicola</i> . | † <i>Rhododermis elegans</i> .    |
| † <i>Porphyra leucosticta</i> .      | <i>Phymatolithon lævigatum</i> .  |
| † <i>Chantransia efflorescens</i> .  | <i>Lithophyllum incrustans</i> .  |
| † <i>C. Daviesii</i> .               | <i>L. hapalidioides</i> .         |
| <i>Choreocolax Polysiphoniæ</i> .    | † <i>Sorapion Kjellmani</i> .     |
| † <i>Harveyella mirabilis</i> .      | † <i>Myrionema foecundum</i> .    |
| <i>Callophyllis laciniata</i> .      | † <i>M. speciosum</i> .           |
| <i>Callocolax neglectus</i> .        | † <i>Chilionema reptans</i> .     |
| <i>Sterrocolax decipiens</i> .       | <i>Microsyphar Zosteræ</i> .      |
| † <i>Lomentaria articulata</i> .     | <i>Ectocarpus velutinus</i> .     |
| <i>Nitophyllum laceratum</i> .       | † <i>E. lucifugus</i> .           |
| <i>Laurencia pinnatifida</i> .       | <i>E. dasycarpus</i> .            |
| <i>Polysiphonia violacea</i> .       | <i>E. granulosus</i> .            |
| † <i>P. Brodiaei</i> .               | <i>Elachista scutulata</i> .      |
| † <i>P. elongata</i> .               | <i>Sphacelaria cæspitula</i> .    |
| <i>P. atrorubescens</i> .            | <i>S. furcigera</i> .             |
| <i>Rhodomela subfusca</i> .          | † <i>S. cirrhosa</i> .            |
| <i>Griffithsia setacea</i> .         | <i>Cladostephus spongiosus</i> .  |
| † <i>Callithamnion polyspermum</i> . | <i>Desmotrichum undulatum</i> .   |
| † <i>C. corymbosum</i> .             | <i>Punctaria latifolia</i> .      |
| <i>C. granulatum</i> .               | † <i>Asperococcus echinatus</i> . |
| † <i>Ceramium Boergesenii</i> .      | † <i>Litosiphon Laminariæ</i> .   |
| <i>Rhodochorton seiriolanum</i> .    | † <i>Phæostroma parasiticum</i> . |
| † <i>Furcellaria fastigiata</i> .    | † <i>Himanthalia lorea</i> .      |
| † <i>Polyides rotundus</i> .         | † <i>Halidrys siliquosa</i> .     |
| † <i>Cruoriella Dubyi</i> .          |                                   |

Possibly many of these species, perhaps almost half of them, are to be found in S. and SW. Iceland. The 26 species marked with a † before the name may possibly be found in Iceland, though with many of them this is doubtful.

If it should appear from further investigations that some of the species considered not common to the Færøes and Iceland are common to them, it should not be assumed from this that the floristic

resemblance is increased, as it is highly probable that other species which are not common would be simultaneously found.

From the coast of Norway I select Finmark for comparison with Iceland, which comparison gives the following figures: —

Iceland 143 species		Finmark 125 species	
not common	common	not common	common
45 (26 0/0)	98 (58 0/0)	27 (16 0/0)	

A comparison between Finmark and SW. Iceland gives the following figures: —

SW. Iceland 115 species		Finmark 125 species	
not common	common	not common	common
29 (19 0/0)	86 (56 0/0)	39 (25 0/0)	

The following are the 45 species which are found in Iceland and are absent from Finmark: —

1 <i>Porphyropsis coccinea</i> .	24 <i>Ralfsia ovata</i> .
2 <i>Chantransia Alariæ</i> .	25 <i>R. clavata</i> .
3 <i>Phyllophora membranifolia</i> .	26 <i>R. verrucosa</i> .
4 <i>Ceratocolax Hartzii</i> .	27 <i>Myrionema Laminiariæ</i> .
5 <i>Lomentaria rosea</i> .	28 <i>M. Corunnæ</i> .
6 <i>L. clavellosa</i> .	29 <i>M. globosum</i> .
7 <i>Plocamium coccineum</i> .	30 <i>M. færøense</i> .
8 <i>Delesseria Baerii</i> .	31 <i>Ascocyclus islandicus</i> .
9 <i>Bonnemaisonia asparagoides</i> .	32 <i>Microsyphar Polysiphoniæ</i> .
10 <i>Pterosiphonia parasitica</i> .	33 <i>Ectocarpus Stilophoræ</i> .
11 <i>Callithamnion Arbuscula</i> .	34 <i>E. tomentosoides</i> .
12 <i>Ceramium acanthonotum</i> .	35 <i>E. tomentosus</i> .
13 <i>C. fruticosum</i> .	36 <i>E. Hinksia</i> .
14 <i>C. arborescens</i> .	37 <i>Sphacelaria radicans</i> .
15 <i>C. atlanticum</i> .	38 <i>S. olivacea</i> .
16 <i>Rhodochorton minutum</i> .	39 <i>Omphalophyllum ulvaceum</i> .
17 <i>R. repens</i> .	40 <i>Litosiphon filiformis</i> .
18 <i>Dilsea edulis</i> .	41 <i>Phæostroma pustulosum</i> .
19 <i>Petrocelis Hennedyi</i> .	42 <i>Phyllitis zosterifolia</i> .
20 <i>Cruoria arctica</i> .	43 <i>Dictyosiphon Mesogloia</i> .
21 <i>C. pellita</i> .	44 <i>Desmarestia ligulata</i> .
22 <i>Rhododermis parasitica</i> .	45 <i>Laminaria færøensis</i> .
23 <i>Petroderma maculiforme</i> .	

Of these species ten (Nos. 3, 6, 7, 10, 11, 12, 18, 21, 26 and 35) are known from Nordland and therefore might possibly be found also in Finmark. Furthermore, nine of the species (Nos. 2, 5, 9, 25, 33, 34, 35, 40, 44) are known from West Norway, and the majority of these will also be found, without doubt, in Nordland and Fin-

mark. Of the remaining 23 species the greater number will certainly be found in Finmark. But I think it less probable that *Omphalophyllum ulvaceum* and *Laminaria færoënsis* are to be met with there, while one can form no opinion as to whether the endemic Icelandic species (17 and 31) exist in Finmark, as their distribution outside Iceland is unknown. On the other hand I think it somewhat probable that the Icelandic-Færøese species *Myrionema færoëse* may occur in Finmark.

The 27 species, which are present in Finmark and absent from Iceland, are the following: —

Chantransia efflorescens.	Ectocarpus terminalis.
C. Daviesii.	E. nanus.
Harveyella mirabilis.	E. ovatus.
Polysiphonia elongata.	Myriotrichia filiformis.
Spermothamnion Turneri.	Sphacelaria racemosa.
Furcellaria fastigiata.	S. cirrhosa.
Polyides rotundus.	Phæosaccion Collinsii.
Petrocelis Middendorffii.	Asperococcus echinatus.
Phymatolithon investiens.	Delamarea attenuata.
Lithothamnion intermedium.	Dictyosiphon hispidus.
L. fornicatum.	Laminaria Agardhii.
Lithoderma lignicola.	Haplospora globosa.
Myrionema foecundum.	Halidrys siliquosa.
Chilionema reptans.	

The majority of these species may be expected to occur on the coasts of Iceland, but there is less probability of *Laminaria Agardhii* being met with there.

If we turn to E. Iceland and compare this with the White Sea we obtain the following figures: —

E. Iceland 80 species		White Sea 52 species	
not common	common	not common	
43 (45 %)	37 (39 %)	15 (16 %)	

The floristic similarity is somewhat considerable, and ten of the species peculiar to the White Sea are known from other parts of the coast of Iceland. These ten species are *Dilsea edulis*, *Cystoclonium purpurascens*, *Polysiphonia nigrescens*, *Delesseria alata*, *Ptilota plumosa*, *Lithothamnion Lenormandi*, *Corallina officinalis*, *Dictyosiphon hippuroides*, *Fucus serratus*, and *Pelvetia canaliculata*.

Of these species, however, only an extremely small number can be expected to occur in E. Iceland.

The five species present in the White Sea and entirely absent from Iceland are: —

*Chantransia efflorescens.*  
*Furcellaria fastigiata.*  
*Polyides rotundus.*

*Sphacelaria racemosa.*  
*Laminaria Agardhii.*

With the exception of *Laminaria Agardhii* all these species certainly may be met with on the coasts of Iceland, but in E. Iceland one can scarcely expect to find others than *Chantransia efflorescens* and *Sphacelaria racemosa*.

If we compare Iceland and E. Iceland with West Greenland and East Greenland we get the following figures: —

Iceland 143 species		West Greenland 108 species	
not common	common	not common	
62 (36 %)	81 (48 %)	27 (16 %)	
Iceland 143 species		East Greenland 85 species	
not common	common	not common	
79 (48 %)	64 (39 %)	21 (13 %)	
E. Iceland 80 species		West Greenland 108 species	
not common	common	not common	
11 (9 %)	69 (58 %)	39 (33 %)	
E. Iceland 80 species		East Greenland 85 species	
not common	common	not common	
23 (21 %)	57 (53 %)	28 (26 %)	

The species present in Iceland and absent from West Greenland are the following: —

*Porphyropsis coccinea.*  
*Chantransia Alariæ.*  
*Phyllophora membranifolia.*  
*Ahnfeltia plicata.*  
*Chondrus crispus.*  
*Gigartina mamillosa.*  
*Cystoclonium purpurascens.*  
*Lomentaria rosea.*  
*L. clavellosa.*  
*Plocamium coccineum.*  
*Delesseria alata.*  
*D. sanguinea.*  
*Bonnemaisonia asparagoides.*  
*Polysiphonia fastigiata.*  
*P. nigrescens.*  
*Pterosiphonia parasitica.*  
*Odonthalia dentata.*  
*Callithamnion scopulorum.*  
*C. Arbuscula.*  
*Plumaria elegans.*

*Ptilota plumosa.*  
*Ceramium acanthototum.*  
*C. Deslongchampii.*  
*C. fruticulosum.*  
*C. circinnatum.*  
*C. arborescens.*  
*C. atlanticum.*  
*Rhodochorton minutum.*  
*R. repens.*  
*Dumontia filiformis.*  
*Dilsea edulis.*  
*Petrocelis Hennedyi.*  
*Cruoria pellita.*  
*Rhododermis parasitica.*  
*Phymatolithon polymorphum.*  
*Lithothamnion Lenormandi.*  
*L. flavescens.*  
*L. Ungerii.*  
*Lithophyllum Crouani.*  
*Dermatolithon macrocarpum.*



Corallina officinalis.	Dictyosiphon Ekmani.
Petroderma maculiforme.	D. Mesogloia.
Myrionema Laminariæ (in E. Greenl.)	Desmarestia ligulata.
M. vulgare.	Leathesia difformis.
M. Corunnæ.	Laminaria saccharina (in E. Greenl.)
M. færøense.	L. færøensis.
Ascocyclus islandicus.	L. hyperborea.
Ectocarpus tomentosus.	Alaria esculenta (in E. Greenl.)
E. fasciculatus.	Fucus spiralis.
E. Hinksia.	F. serratus.
Sphacelaria olivacea.	Pelvetia canaliculata.

Of the 57 species here mentioned three are found in East Greenland; viz. *Myrionema Laminariæ*, *Laminaria saccharina* and *Alaria esculenta*. It is most probable that none of these 57 species will be met with in West Greenland, with the exception, perhaps, of some of the *Myrionema*-species.

There are 74 species absent from East Greenland which are found in Iceland. Of these, 54 species have already been mentioned (see above), and to these must be added 20 species which are absent from East Greenland but present in West Greenland and Iceland. These species are the following: —

Bangia fuscopurpurea.	Ectocarpus Stilophoræ.
Porphyra umbilicalis.	E. tomentosoides.
Chantransia secundata.	E. penicillatus.
C. virgatula.	Sphacelaria radicans.
Polysiphonia urceolata.	Litosiphon filiformis.
Antithamnion floccosum.	Phyllitis zosterifolia.
Ceramium rubrum.	Dictyosiphon Chordaria.
Ralfsia ovata.	D. corymbosus.
R. verrucosa.	D. hippuroides.
Microsyphar Polysiphoniæ.	Castagnea virescens.

It seems most probable that these 20 species are to be met with in East Greenland.

The 11 species present in E. Iceland and absent from West Greenland are included in the above-mentioned figure. They are: —

Gigartina mamillosa.	Laminaria saccharina (in E. Greenl.)
Delesseria sangvineæ.	L. færøensis.
Odonthalia dentata.	L. hyperborea.
Dumontia filiformis.	Alaria esculenta (in E. Greenl.)
Lithothamnion flavescens.	Fucus spiralis.
L. Ungerii.	

The 23 species present in E. Iceland and absent from East Greenland have also been already recorded. With the addition of the 9 of the above-mentioned species they are the following: —



*Bangia fuscopurpurea.*  
*Porphyra umbilicalis.*  
*Chantransia secundata.*  
*Polysiphonia urceolata.*  
*Antithamnion floccosum.*  
*Ralfsia verrucosa.*  
*Ectocarpus Stilophoræ.*

*Ectocarpus tomentosoides.*  
*E. penicillatus.*  
*Sphacelaria radicans.*  
*Litosiphon filiformis.*  
*Phyllitis zosterifolia.*  
*Dictyosiphon Chordaria.*  
*Castagnea virescens.*

These species might possibly also be found in East Greenland, as they are already known from West Greenland (see above), and in that case there could be only 9 E. Iceland-species which were not known from East Greenland.

In West Greenland there are 27 species which are not found in Iceland. These are: —

Ø *Harveyella mirabilis.*  
*Callymenia sangvinea.*  
*Delesseria Montagnei.*  
*Polysiphonia elongata.*  
*Ceramium Areschoughii.*  
*C. septentrionale.*  
 Ø *Rhododermis elegans.*  
*Lithothamnion intermedium.*  
*Chantransia collopoda.*  
 Ø *Sorapion Kjellmani.*  
*Ectocarpus Pringsheimii.*  
 Ø *E. ovatus.*  
 Ø *E. pycnocarpus.*  
 Ø *E. maritimus.*

Ø *Sphacelaria racemosa.*  
*Phæosaccion Collinsii.*  
 Ø *Symphyocarpus strangulans.*  
*Kjellmania subcontinua.*  
*Coelocladia arctica.*  
 Ø *Delamarea attenuata.*  
*Dictyosiphon hispidus.*  
*Myriocladia cailitricha.*  
 Ø *Laminaria solidungula.*  
 Ø *L. longicruris.*  
*L. cuneifolia.*  
 Ø *L. groenlandica.*  
 Ø *Agarum Turneri.*

Of these species 13 (with Ø prefixed) are found in East Greenland.

In East Greenland 21 species are found which are not known from Iceland. In addition to the 13 above-mentioned species, they are the following: —

*Chantransia efflorescens.*  
*Dilsea integra.*  
*Petrocelis polygya.*  
*Cruoriopsis hyperborea.*

*Ectocarpus helophorus.*  
*Haplospora globosa.*  
*Punctaria glacialis.*  
*Myrionema foecundum.*

The greater number of the West Greenland and East Greenland species here mentioned will probably be met with in Iceland, especially on the north and east coasts. It is less likely, however, that the following species will be found in Iceland: — *Callymenia sanguinea*, *Delesseria Montagnei*, *Dilsea integra*, *Petrocelis polygya*, *Laminaria solidungula*, *L. cuneifolia*, *L. groenlandica* and *Agarum Turneri*.

According to the above comparisons Iceland most nearly resembles Finmark, and next to that place the Færøes; the resemblance to West

Greenland is rather less, and to East Greenland is least of all, as the following figures show: —

	common	not common
Iceland—Finmark . . . . .	58 $\frac{0}{0}$	42 $\frac{0}{0}$
Iceland—the Færøes . . . . .	55 $\frac{0}{0}$	45 $\frac{0}{0}$
Iceland—West Greenland . . . . .	48 $\frac{0}{0}$	52 $\frac{0}{0}$
Iceland—East Greenland . . . . .	39 $\frac{0}{0}$	61 $\frac{0}{0}$

S. Iceland is too little known to be compared with other districts, as has already been emphasized above. The resemblance to the Færøes will certainly prove to be much greater than is shown by the figures now known.

	common	not common
S. Iceland—the Færøes . . . . .	44 $\frac{0}{0}$	56 $\frac{0}{0}$
S. and SW. Iceland—the Færøes .	55 $\frac{0}{0}$	45 $\frac{0}{0}$

S. Iceland and SW. Iceland together resemble the Færøes to the same degree as do the coasts of Iceland taken as a whole. The fact that S. Iceland least resembles the Færøes is merely due to a deficient knowledge of its coasts.

As regards SW. Iceland—Finmark the percentage of species common to both places is 56 and that of not common 44. Thus, the resemblance is somewhat less than that between Iceland and Finmark.

If we now turn to E. Iceland we obtain the following figures: —

	common	not common
E. Iceland—West Greenland . . . . .	58 $\frac{0}{0}$	42 $\frac{0}{0}$
E. Iceland—East Greenland . . . . .	53 $\frac{0}{0}$	47 $\frac{0}{0}$
E. Iceland—White Sea . . . . .	39 $\frac{0}{0}$	61 $\frac{0}{0}$

E. Iceland has thus the greatest floristic resemblance to West Greenland, resembles East Greenland somewhat less and the White Sea least of all, although the floral districts of E. Iceland and the White Sea resemble each other most closely when the species are grouped according to geographical distribution (see above).

## V. THE VERTICAL DISTRIBUTION OF THE SPECIES.

IF we walk along the beach at low-tide we see a belt laid bare, the breadth of which varies according to the degrees of declivity of the coast and according to the tides — that is according to whether it is spring-tide or neap-tide. At spring-tide the belt is broad and at neap-tide narrow. The low-water mark of neap-tide divides the belt laid bare into two parts, an upper part which is laid bare during every low-tide and a lower part which is laid bare only at and about spring-tide. The upper part, between the upper limit of growth of the algal vegetation and the low-water mark of neap-tide, which almost coincides with the lower edge of the *Fucaceæ*-belt, I call the Upper Littoral Zone. The lower part, from the lower edge of the *Fucaceæ*-belt to the usual<sup>1</sup> low-water mark of spring-tide, I call the Lower Littoral Zone. Below low-water mark of spring-tide begins the vegetation which is constantly submerged. That the vegetation of the lower littoral zone is closely connected with that in the upper part of the constantly-submerged zone is natural and will be discussed subsequently.

In the following table a dash (—) denotes a habitat (depth) in which the species has been found many times, and a dot (·) one in which it has been found either once or comparatively rarely.

Table 7. The Vertical Distribution of the Species.

	Littoral zone		Depth (metre)														88
	upper	lower	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	65-70	
<b>Rhodophyceæ.</b>																	
1 <i>Bangia fuscopurpurea</i> .....	—																
sl <i>Porphyra miniata</i> .....		—	—	—													

<sup>1</sup> No notice is taken of the extraordinarily low ebb-tides which occasionally occur and by which large *Laminariæ* are often exposed.

Table 7. The Vertical Distribution of the Species (continued).

	Littoral zone		Depth (metre)														88
	upper	lower	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	
1 <i>Porphyra umbilicalis</i> .....	—	—															
s <i>Porphyropsis coccinea</i> .....				.		—											
s <i>Conchocelis rosea</i> .....	.			.	.		.	.	.								
sl <i>Chantransia microscopica</i> .....	.	.															
s <i>C. Alariæ</i> ,.....				—													
sl <i>C. secundata</i> .....	.	—															
sl <i>C. virgatula</i> .....	.	—															
sl <i>Chondrus crispus</i> .....		—	.														
sl <i>Gigartina mamillosa</i> .....	.	—		.	.	.											
sl <i>Ahnfeltia plicata</i> .....		—		.	.	.											
s <i>Phyllophora Brodiaei</i> v. <i>interrupta</i> ,.				.	.	.	.	.									
sl <i>P. membranifolia</i> .....		—															
s <i>Actinococcus subcutaneus</i> .....						.	.	.									
s <i>Ceratocolax Hartzii</i> .....								.									
sl <i>Cystoclonium purpurascens</i> .....		—	.														
s <i>Turnerella Pennyi</i> .....			.		.					—		.	.	.			
s <i>Euthora cristata</i> .....			.	—	—	—	—	—	—		.						
s <i>Rhodophyllis dichotoma</i> .....			.	—	—	—	—	—	—								
sl <i>Rhodymenia palmata</i> .....	—	—	—	—	.	.											
s <i>Lomentaria clavellosa</i> .....				.	—	—	—	—	—	—							
s <i>L. rosea</i> .....				.	—	—	—	—	—	—							
s <i>Plocamium coccineum</i> .....			.	.	—	—	—	—	—	—							
sl <i>Halosaccion ramentaceum</i> .....	—	—	—	—	—	—	—	—	—	—							
s <i>Delesseria alata</i> .....	—	—	—	—	—	—	—	—	—	—							
<i>D. Baerii</i> * <i>corymbosa</i> .....																	
s <i>D. sinuosa</i> .....			.	—	—	—	—	—	—	—	—	.	.	.			
s <i>D. sanguinea</i> .....	—	—	—	—	—	—	—	—	—	—							
<i>Bonnemaïsonia asparagoides</i> .....																	
s <i>Polysiphonia urceolata</i> .....	.	—	—	—	—	.	.	.	.	.							
l <i>P. fastigiata</i> .....	—	—															
s <i>P. arctica</i> .....			.	.	—	—	—	—	—	—	—	—	—	—	.		
sl <i>P. nigrescens</i> .....	.			.													
s <i>Pterosiphonia parasitica</i> .....						.	.	.									
sl <i>Rhodomela lycopodioides</i> .....	—	—	—	—	—												
s <i>Odonthalia dentata</i> .....			.	—	—	—	—	—	—	.							
sl <i>Callithamnion Arbuscula</i> .....	.	—															
sl <i>C. scopulorum</i> .....	.	—															
sl <i>Plumaria elegans</i> .....	.	—															
s <i>Ptilota plumosa</i> .....			.	—	—	—	—	—	—	—	—	—	—	.	.	.	
s <i>P. pectinata</i> .....			.	—	—	—	—	—	—	—	—	.	.	.	.		
s <i>Antithamnion Plumula</i> v. <i>boreale</i> ..			—	.	.	.											
sl <i>A. floccosum</i> .....	—	—	—	—	—	—	—	—	—	—							
sl <i>Ceramium Deslongchampsii</i> .....	.																





Table 7. The Vertical Distribution of the Species (continued).

	Littoral zone		Depth (metre)															
	upper	lower	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	88	
sl Myrionema Laminariæ .....	.	.																
sl Ascoecylus islandicus .....	.	.																
sl Microsyphar Polysiphoniæ .....	.	.																
s Streblonema æcidioides .....	.	.																
sl S. Stilophoræ v. cæspitosa .....	—	—																
l Pylaiella littoralis .....	—	—			.													
s Ectocarpus tomentosoides .....	—	—				—												
l E. tomentosus .....	—	—																
sl E. confervoides .....	—	—			.													
sl E. siliculosus .....	—	—			.													
sl E. penicillatus .....	—	—																
sl E. fasciculatus .....	—	—																
s E. Hinksii .....	—	—																
sl Leptonema fasciculatum v. subcylindrica ..	.	.																
l Elachista fucicola .....	—	—	.	.														
l Sphacelaria britannica .....	—	—																
sl S. radicans .....	.	.	—	—														
s S. olivacea .....	.	.																
s Chaetopteris plumosa .....	—	—			.	.												
s Omphalophyllum ulvaceum .....	—	—						—	—	—		.	.	.				
sl Punctaria plantaginea .....	—	—																
sl Litosiphon filiformis .....	—	—																
l Isthmoplea sphærophora .....	—	—																
sl Stictyosiphon tortilis .....	—	—	.	.	.													
sl Phæostroma pustulosum .....	.	.	.	.	.													
sl Scytosiphon Lomentaria .....	.	—																
sl Phyllitis zosterifolia .....	—	—	.	.	.													
sl P. fascia .....	—	—																
sl Coilodesme bulligera .....	.	—																
sl Dictyosiphon Ekmani .....	.	.																
sl D. Mesogloia .....	.	.																
sl D. Chordaria .....	.	.																
sl D. corymbosus .....	.	.																
sl D. hippuroides .....	.	.																
sl D. feniculaceus .....	—	—	.	.														
s Desmarestia viridis .....	.	.	.	.							.	.	.	.				
s D. aculeata .....	.	.		—							.	.	.	.				
s D. ligulata .....	.	.					?				.	.	.	.				
sl Castagnea virescens .....	.	.	.															
sl Leathesia difformis .....	—	—																
sl Chordaria flagelliformis .....	—	—	.	.	.													
s Chorda tomentosa .....	.	.						.	.									





Table 7. The Vertical Distribution of the Species (continued).

	Littoral zone		Depth (metre)															
	upper	lower	1—5	6—10	11—15	16—20	21—25	26—30	31—35	36—40	41—45	46—50	51—55	56—60	61—65	66—70	88	
1 <i>Acrochaete parasitica</i> . . . . .	.																	
sl <i>A. repens</i> . . . . .		?	?															
sl <i>Bolbocoleon piliferum</i> . . . . .	.	—																
1 <i>Ulvella fucicola</i> . . . . .	.																	
sl <i>Pringsheimia scutata</i> . . . . .	.	.	.	.														
1 <i>Ochlochaete ferox</i> . . . . .	.																	
1 <i>Urospora mirabilis</i> . . . . .	—																	
1 <i>U. Hartzii</i> . . . . .	—																	
sl <i>U. Wormskioldii</i> . . . . .	—	.	.															
1 <i>Chaetomorpha tortuosum</i> . . . . .	—																	
sl <i>C. Melagonium</i> . . . . .	—	—	—	—														
1 <i>Rhizoclonium riparium</i> . . . . .	—																	
sl <i>Spongomorpha vernalis</i> . . . . .	—	.	.															
1 <i>Acrosiphonia albescens</i> . . . . .	—																	
sl <i>A. incurva</i> . . . . .	—	.	.															
sl <i>A. hystrix</i> . . . . .	—	—	—	—				.	.									
1 <i>A. flabelliformis</i> . . . . .	.																	
1 <i>A. penicilliformis</i> . . . . .	.																	
1 <i>Cladophora rupestris</i> . . . . .	—																	
1 <i>C. hirta</i> . . . . .	.																	
1 <i>C. sericea</i> . . . . .	—																	
1 <i>C. glaucescens</i> . . . . .	.																	
1 <i>C. gracilis</i> . . . . .	.																	
s <i>Gomontia polyrrhiza</i> . . . . .			.	.	.	.	.	.	.	.	.							
s <i>Ostreobium Queketti</i> . . . . .			.	.	.	.	.	.	.	.	.							
<b>Cyanophyceæ.</b>																		
1 <i>Pleurocapsa amethystea</i> . . . . .	—																	
1 <i>Plectonema norvegicum</i> . . . . .	.																	
1 <i>Phormidium autumnale</i> . . . . .	.																	
1 <i>Spirulina subsalsa</i> . . . . .	.																	
1 <i>Calothrix scopulorum</i> . . . . .	—																	
1 <i>Rivularia atra</i> . . . . .	.																	
<b>Fungi.</b>																		
<i>Dothidella Laminariæ</i> . . . . .			—	—	—	—	—	.	.	.	.							

**A. Upper Littoral Zone.**

The preceding table shows that 18 species of *Rhodophyceæ*, 18 species of *Phaeophyceæ*, 36 species of *Chlorophyceæ* and 6 species of *Cyanophyceæ* grow in the upper littoral zone; that is, 78 species

in all. Of these species some are common and others rare; some are found exclusively in the upper littoral zone and others extend further downwards. In order to show this more distinctly, each group will here be dealt with separately and in detail.

**Rhodophyceæ.** Of the 18 species mentioned 5 are common, and the remaining 13 rarer. The following are the commonly distributed species: *Bangia fuscopurpurea*, which is found exclusively in the upper littoral zone; *Porphyra umbilicalis* which is found also in the lower littoral zone; *Polysiphonia fastigiata* which occurs exclusively on *Ascophyllum nodosum* in the upper littoral zone; *Rhodochorton Rothii* which extends to a depth of 10 metres, and *Hildenbrandia rosea* which extends to a depth of 5 metres. The three first-named species are common in places exposed to the light in the littoral zone; *Rhodochorton* and *Hildenbrandia*, on the other hand, occur most frequently as an undergrowth, or in shady clefts (*Rhodochorton*), and at the bottom of pools (*Hildenbrandia*). These two species are met with more rarely in places exposed to the light. The 13 species which occur in the upper littoral zone, but which must be called somewhat rare, are there shade-loving, and are then found either as an undergrowth or in shady clefts and depressions. Some are epiphytes, and are then protected against desiccation by the host-plant. The greater number of these 13 species are common in the lower littoral zone, and the 3 *Ceramium*-species which are recorded exclusively from the upper littoral zone may doubtless be expected to occur also in the lower littoral zone. *Conchocelis* does not occur in the lower littoral zone but is found at a depth of 6—35 metres.

**Phæophyceæ.** Of brown algæ the *Fucaceæ* play the most important rôle. The species are few in number, but are of social growth, and occur in such quantities that they comprise by far the greater portion of the bulk of the plants in the upper littoral zone. Of the 18 species mentioned above, 12 are commonly distributed, and 6 are more rare, in the upper littoral zone. Of the 12 common species, 9 are found exclusively in the upper littoral zone, viz., 6 species of *Fucaceæ*, *Sphacelaria britannica*, *Ectocarpus lomentosus* and *Ralfsia clavata*; *Pylaiella littoralis*, *Elachista fucicola* and *Isthmoplea*, on the other hand, range to a depth of about 10 metres. Of the rarer species, *Petroderma* is found exclusively in the upper littoral zone, *Ralfsia verrucosa* is most frequent in the upper littoral zone, but is also met with in the lower littoral zone, as an epi-

phyte; the remaining 4 species are common in the lower littoral zone, and occur in pools in the upper littoral zone, consequently they cannot, strictly speaking, be reckoned as belonging to the upper littoral zone.

**Chlorophyceæ.** In the table, 36 species of green algæ are mentioned from the upper littoral zone. Of these, 15 are characterized as common and 21 as rarer. 31 species are recorded exclusively from the upper littoral zone; 2 species, *Entoderma* and *Bolbocoleon* are more frequent in the lower littoral zone; one species *Chlorochytrium dermatocolax* is as frequent in the lower littoral zone as in the upper littoral zone, one species *Ulothrix flacca*, which must be considered a decidedly littoral species, grows to a depth of about 10 metres. *Ulvella fucicola* also grows to a depth of 5 metres, but must nevertheless be considered littoral. In addition to these 36 species, others may be found in the upper littoral zone, which have a more downward extension (e. g. *Monostroma Grevillei* var. *arctica*, *M. fuscum*, *Acrosiphonia incurva*, and others), but they generally keep to the pools.

**Cyanophyceæ.** All the species hitherto found (6) grow in the upper littoral zone.

The species which are recorded from the upper littoral zone may be put into two divisions. The one comprises the species which are common in the upper littoral zone and are adapted to growth in places exposed to the light and the wind during the period of exposure; these species, then, might be termed strictly littoral. The other division comprises species which are common in the lower littoral zone or extend even further downwards. The greater number of these species does not occur in the open littoral zone, but is found as an undergrowth or in shady clefts, or in pools. The real home of these species is lower down than in the upper littoral zone, and for this reason they can scarcely be designated littoral species.

According to the above, there are in all 58 strictly littoral species: *Rhodophyceæ* 5 species, *Phæophyceæ* 14 species, *Chlorophyceæ* 33 species and *Cyanophyceæ* 6 species.

The upper littoral zone is thus essentially characterized by a paucity of species of red algæ, by many species of green algæ and by a preponderance of *Fucaceæ*. The number of the species of brown algæ is of less importance; it is three times as large as that of the red algæ and about half as large as that of the green algæ.

If we reckon, in percentages, the number of species of each group of the total number of species in the upper littoral zone we obtain the following figures. The strictly littoral species (58 in all) are indicated by *a*, the other species (20 in all) not strictly littoral are indicated by *b*, but no attention is paid to those species which may be found in the upper littoral zone and appear to grow by preference in pools.

	Rhodophyceæ	Phæophyceæ	Chlorophyceæ	Cyanophyceæ
<i>a</i> .....	5 (9 0/0)	14 (24 0/0)	33 (57 0/0)	6 (10 0/0)
<i>a</i> + <i>b</i> .....	18 (23 0/0)	18 (23 0/0)	36 (46 0/0)	6 (8 0/0)

So far as the abundance of species is concerned I lay special stress on the red algæ, green algæ and blue-green algæ. It would be confusing, especially as regards the red algæ, to reckon the *b*-species as strictly littoral, nor can this be done, because they are not adapted for life in the open littoral zone. As regards the brown and green algæ, on the other hand, it is of no essential importance whether the *b*-species are included or not, as they are so few in number.

If we calculate how great a proportion the strictly littoral species form of the combined number of each group we obtain the following figures: —

	Rhodophyceæ	Phæophyceæ	Chlorophyceæ	Cyanophyceæ
Species known at present from Iceland..	76	67	51	6
Strictly littoral species	5 (6.6 0/0)	14 (20.9 0/0)	33 (64.7 0/0)	6 (100 0/0)
<i>a</i> + <i>b</i> (see above)....	18 (23.7 0/0)	18 (26.8 0/0)	36 (70.6 0/0)	6 (100 0/0)

## B. The Lower Littoral Zone and the Belt below down to a depth of about 10 metres.

1. The Lower Littoral Zone. From this are recorded 93 species in all (Table 7), viz. 39 *Rhodophyceæ*, 37 *Phæophyceæ* and 17 *Chlorophyceæ*. Of these 93 species, the upper and lower littoral zones have 15 species in common (8 red, 5 brown, 2 green) which do not extend further downwards; the greater number of these belong, strictly speaking, to the lower littoral zone, as, in the upper littoral zone, they usually occur in pools or very shady spots. 19 species (8 red, 11 brown) have been found only in the lower littoral zone; but the majority of them probably occur also below the limit of low-tide, and, in any case, some have their area of distribution



close to this limit; 6 species (1 red, 3 brown, 2 green) have their area of distribution in the upper and lower littoral zones, and to a depth of 10 metres, these species are mentioned under the Upper Littoral Zone, and there, 5 of them are reckoned as littoral. 35 species (10 red, 15 brown, 10 green) grow in the lower littoral zone, and to a depth of about 10 metres. They appear to be about as common in the lower littoral zone as in the belt between the limit of low-tide and the depth mentioned. 18 species (12 red, 3 brown, 3 green) grow in the lower littoral zone, and to a depth of more than 10 metres; these belong to the species which have a lower downward range, 15 of them have their uppermost limit in the lower littoral zone, and 3 of them in the upper littoral zone.

The species characteristic of the lower littoral zone are especially the 19 species which are found there only, and the 35 species which extend to a depth of about 10 metres, for some of these (e. g. *Rhodymenia* and *Halosaccion*), by occurring in masses, often characterize large portions of the lower littoral zone.

2. The Belt down to a depth of about 10 metres. In the table 103 species are recorded from this belt. Of these, two occur also in the upper littoral zone, and have been previously mentioned (*Rhodochorton Rothii* and *Hildenbrandia*), 6 occur also in the upper and lower littoral zones and are mentioned above, 35 occur also in the lower littoral zone (see under this heading); while 9 species are found only at this depth, but of these some may be presumed to extend further downwards and some may possibly occur in the lower littoral zone. 19 species extend downwards, with their uppermost limit in the upper and lower littoral zones, as, for example, *Conchocelis rosea* which occurs in the upper littoral zone and is absent from the lower littoral zone, besides the 18 species mentioned under the Lower Littoral Zone. 32 species with a downward range have their uppermost limit at a depth of about 10 metres.

Besides the 9 species which are found only in this belt, it is especially the 35 species which this belt has in common with the lower littoral zone which characterize the belt, as some of them — those mentioned under the Lower Littoral Zone — by occurring in masses often characterize large portions of the bottom.

By comparison it can easily be seen that the lower littoral zone is much more closely related to this belt than to the upper littoral zone, which, amongst other things, is evident from the great



number of red algæ in the lower littoral zone. This can be distinctly seen from the following figures: —

Upper Littoral Zone		Lower Littoral Zone	
58 species ( <i>a</i> )		93 species	
not common	common	not common	
51 (35.42 %)	7 (4.86 %)	86 (59.72 %)	
Upper Littoral Zone		Lower Littoral Zone	
78 species ( <i>a</i> + <i>b</i> )		93 species	
not common	common	not common	
54 (36.73 %)	24 (16.33 %)	69 (46.94 %)	
Lower Littoral Zone		From the limit of low-tide to a depth of about 10 m. 103 species.	
93 species		not common	
not common	common	not common	
34 (24.82 %)	59 (43.06 %)	44 (32.12 %)	

The figures show that the upper littoral zone is very unlike the lower littoral zone, especially if only the species which are characteristic of the latter, or which occur in the open littoral zone (*a*), are taken into consideration, which is most correct, as the shade-loving species in the upper littoral zone must be regarded as stragglers from associations lower down. As previously mentioned, the lower littoral zone bears the greatest resemblance to the belt which exists lower down (to a depth of about 10 metres).

The species which have their lower limit of growth at a depth of about 10 metres and which are commonly distributed in the lower littoral zone I designate semi-littoral because they are found both laid bare during low-tide in the lower littoral zone and constantly submerged in the belt below; as these species especially characterize the lower littoral zone and the belt below to a depth of about 10 metres I designate this area the semi-littoral zone. It must not be concluded, however, that semi-littoral vegetation covers the bottom everywhere down to a depth of 10 metres; below the limit of low-tide the semi-littoral vegetation appears rather to consist of stragglers from the lower littoral zone into the *Laminaria*-belt. Thus the semi-littoral zone is situated between the *Fucus*-belt and the *Laminaria*-belt. The species which specially occur in the semi-littoral zone I designate on the whole as semi-littoral, also those which are found in the lower littoral zone and are not found below the limit of low-tide; they will probably be found also below this limit. Species which are common in the lower littoral zone and are rare in the

upper littoral zone, but not known below the limit of low-tide I have also designated semi-littoral as they might be expected to grow lower down.<sup>1</sup>

### C. The Sublittoral Species.

These species play the principal rôle in the sublittoral vegetation. This may be characterized in a somewhat similar manner as the vegetation of the upper littoral zone, although conversely as regards red and green algæ, viz. by a large number of red algæ and an extremely small number of green algæ and by the occurrence of a mass of *Laminariaceæ*. In Table 7, these species are marked with an s before the name. Their number is shown by the following figures: —

	Species		
	Littoral	Semi-littoral	Sublittoral
Red <sup>2</sup> .....	5	30	39
Brown .....	14	31	22
Green .....	33	15	3
Blue-green .....	6		
Total...	58	76	64

From a comparison of the number of species of the sublittoral zone with that of the littoral and semi-littoral zones it is seen that it is smallest in the littoral zone, somewhat larger in the sublittoral zone and considerably larger in the semi-littoral zone. Species of green algæ occur most abundantly in the littoral zone, and their number is infinitesimal in the sublittoral zone. Red algæ are most numerous in the sublittoral zone and very scarce in the littoral zone. The brown algæ are more evenly distributed in the different zones, yet they are richest in species in the semi-littoral zone. The blue-green algæ are found exclusively in the littoral zone.

In the semi-littoral zone the large brown algæ do not occur in masses like, for example, the belt of *Fucus* in the upper littoral

<sup>1</sup> As regards the majority of the species (see Table 7) it is easy to decide whether they are littoral, semi-littoral or sublittoral, but there are some species, nevertheless, which it is difficult to refer definitely to any one of the three zones mentioned, and therefore it is sometimes a matter of opinion whether they should be reckoned in the one or the other. By perusing the table these species are easily detected.

<sup>2</sup> Two species, *Delesseria Baerii* and *Bonnemaïsonia asparagoides* are not included as their habitat is unknown to me (see 31, pp. 140, 141).

zone and the belt of *Laminaria* in the sublittoral zone. This is possibly the reason why the semi-littoral zone is richest in species.

In Table 7, 64 species are recorded as sublittoral. Besides these, semi-littoral species occur in this zone, especially as epiphytes, or, more rarely, as undergrowth. 12 species, almost all semi-littoral, which extend to a greater depth than 10 metres are mentioned in the table. In addition, about 14 species can be regarded as epiphytic, particularly in the upper part of the sublittoral zone. The sublittoral vegetation is thus composed of 64 sublittoral species and of about 26 semi-littoral species, or about 90 species in all.

### Lower Limits of Growth.

As far as the lower limit of growth is concerned the species which are found below low-tide must be dealt with collectively. In the following table, which shows the lower limits of growth, all the depths at which species have been known to occur have been, as a rule, taken into consideration, and thus the table does not indicate the depth of their general distribution or the depth at which they form associations (see under Vegetation). In the table, 2 red algæ are omitted, as I have no further knowledge regarding their habitats (31, pp. 140, 141). These species are *Delesseria Baerii* and *Bonnemaisonia asparagoides*. As regards the green algæ it must also be stated that I have not taken into consideration the records from greater depths than 10 metres. I myself am responsible for some of these records; the algæ often were detached, but sometimes it appeared as if they really had been growing at the depth recorded. I always, however, have entertained some doubt concerning this, and consequently prefer at present not to consider records from such depths. Regarding *Chlorochytrium inclusum* the record is correct, as it grew in *Turnerella*, which was attached to the bottom at a depth of 30 metres. For *Gomontia* and *Ostreobium* I have given the most common depth, down to about 40 metres, but I have also obtained these species, growing inside an old shell of *Mya*, from a depth of about 60 metres.

It should be further stated that I do not know the depth to be given for *Desmarestia ligulata*. This species has been found by Ove Paulsen between the Vestmannaeyjar and South-Iceland; I presume that it grew at a depth of about 20 metres.

## Lower Limits of Growth in metres (see Table 7).

	About 5—10	About 15—20	About 25—30	About 35—45	About 60 and more
Red algæ . . . . .	13	10	10	15	7
Brown algæ . . . . .	19	8	4	5	3
Green algæ . . . . .	16	..	1	2	..
Total . . . . .	48	18	15	22	10
			37		

In the above table 113 species are mentioned, of which 48 do not extend to a greater depth than about 10 metres, 18 extend to about 20 metres, 15 to about 30 metres, 22 to about 40 metres and 10 to about 60 metres and more. Thus there appears to be a floristic boundary at a depth of about 10 metres; while another boundary can be faintly distinguished at a depth of from about 30 to 40 metres, as there are 37 species which appear not to extend further downwards; and here, also, is situated the lower limit of growth of most of the *Laminariaceæ* which play the same rôle on the sublittoral bottom as the *Fucaceæ* play in the littoral zone. Exactly where the lower limit of growth, as regards the marine algæ in Iceland, is situated — whether it lies at a depth of about 60 to 80 metres or deeper — I cannot at present decide, but it is most probable that the vegetation at greater depths than 60 metres is, in any case, extremely poor in species.

According to the above statements the lower limits of the algæ are as follows: —

The littoral limit (Upper Littoral Zone) . . . . .	53 species	26.77 %
The limit of low-tide . . . . .	32 —	16.17 %
At about 10 metres . . . . .	48 —	24.24 %
At about 20 metres . . . . .	18 —	9.09 %
At about 30—about 40 metres . . . . .	37 —	18.68 %
At about 60 metres and more . . . . .	10 —	5.05 %

198 species.

By future investigations all these figures will undoubtedly be altered and many of them to no inconsiderable extent; but the four principal boundaries, namely the littoral limit, the 10-metre limit, the 30—40 metre limit and the absolute depth-limit will always remain evident.

As regards the absolute depth-limit I cannot make any definite statement. The dredgings which I myself have undertaken have all been conducted with a small dredge from a small rowing boat.

The positive results which are obtained with this small dredge are satisfactory enough when the material is inspected with sufficient criticism, but it should not be concluded with certainty from a negative result (that is, when absolutely nothing comes up from the bottom) that no plants grow there. In great depths, also, dredging is difficult from a small rowing-boat. In some places only, in SW. Iceland and E. Iceland, have I undertaken dredgings in a depth of about 80 metres, and the result has been negative. In those places where the plummet revealed a clayey bottom, it was certain that no plants were growing there. Off S. and SW. Iceland I have met with no vegetation at a greater depth than about 40 metres, but in Reyðarfjörður in E. Iceland, on the other hand, I have come across plants at as great a depth as about 60 metres. This might indicate that the vegetation extends further downwards in E. Iceland; but as the observations are too few, this point must remain undecided until further investigations are forthcoming.

It was a fairly common occurrence, especially in the fjords of E. Iceland, to encounter sunken fragments of algæ (often strictly littoral species) and of mosses in depths of more than 22 metres. In Seyðisfjörður I came across leaves of *Betula* and *Salix* at a depth of 14—20 metres.

C. H. Ostenfeld (the Ingolf Expedition) found *Lithothamnion laeve* in great quantities at a depth of 88 metres off the north coast of Iceland, and R. Hørring (on board the "Diana," off E. Iceland) found *Lithothamnion tophiforme* at a depth of 70 metres. In depths of from 60 to about 100 metres Hørring found, in addition, fragments of various algæ, amongst which were strictly littoral species, and of mosses which had evidently fallen to the bottom. In order to draw the attention of future investigators to this matter it must further be mentioned that Hørring brought home in spirits a young plant of *Laminaria saccharina* from a depth of from 81 to 104 metres (Mjóifjörður, 14.5.1898, St. XIII) and on the label was written "In the trawl were many large *Laminariæ* which had been torn away from the bottom." The *Laminaria* brought home appeared normal, and, if it had fallen to the bottom could only have lain there for a short time. What is most likely is that the trawl passed over an uneven bottom, and that the *Laminariæ* grew at a lesser depth than that mentioned; or is it possible that the deep-water form of *Laminaria saccharina* ranges so far downwards? I leave it to future investigation to decide this question.



## VI. MARINE ALGAL VEGETATION AND SEA-GRASS VEGETATION.

THE vegetation of the sea is naturally divided into two principal groups: the Plankton composed of the small plants floating passively in the water, and the Benthos which comprises the species attached to a substratum. In this article only the latter is dealt with.

The Benthos<sup>1</sup> falls naturally into two divisions, viz. the lithophilous vegetation, the communities of marine algæ (subformation of marine algæ, Halo-nereid communities, Warming, 72, p. 170), and the vegetation of loose soil (Enhalid-formation, Warming, 72, p. 177).

The Benthos has been divided in different ways. J. G. Agardh in 1836 (*Novitiæ Floræ Sveciæ*) divided the marine vegetation into three zones, a green zone above, a brown zone in the middle and a red zone lowest of all. Lyngbye in the same year, also divided the vegetation into three zones (*Rariora Codana*, printed 1879—80), a zone of green algæ (*Ulvaceæ*) being above, a zone of red algæ in the middle and a zone of *Laminariæ* below this. Ørsted (77), like Agardh, also divided the vegetation in the Øresund into three zones, but Ørsted has the merit of being the first to explain that the division of the zones depends upon the depth to which the light penetrates, and upon the colour of the light at the various depths.

Kjellman has divided the algal Benthos into regions. Where there is a tide, the littoral region is reckoned as being between the highest high-water mark and the lowest ebb-tide mark; where, on the other hand, there is no tide Kjellman reckons the littoral region as extending from the uppermost limit of the algal vegetation to a depth of  $1\frac{1}{2}$ —2 fathoms (34, p. 7). The sublittoral region extends from the lower limit of low-tide, or else from a depth of  $1\frac{1}{2}$

<sup>1</sup> No notice is taken of the bacterial flora of the sea.



—2 fathoms, down to a depth of 20 fathoms; and finally the elittoral region stretches from the 20-fathom contour downwards. This division, unchanged in its main features, is generally employed. The boundary between the littoral and sublittoral regions is, I think, commonly supposed to be rather sharply defined in places with tides, and less sharply defined where tides do not occur.

By this division into three regions the algal Benthos is divided into three belts of different depth. Although the boundary lines thus drawn may be described as floristic boundaries, as regards many species, yet they cannot always be regarded as natural limits of vegetation. If natural limits of vegetation are to be drawn, several factors must be taken into consideration. From depth-records, pure and simple, a somewhat clear idea may naturally be formed of the conditions of light, but not of the salinity and warmth. If the conditions of light, salinity and warmth in those layers of water where the algal vegetation lives were known all the year round it would be easy to characterize the limits of the vegetation. The great importance of the salinity to algal vegetation is well-known and is emphasized by Rosenvinge (63), Svedelius (71), Børge-sen (12) and Kylin (45), amongst others.

The ecological factors in the coastal waters round Iceland are not so well known that I am able to draw the natural limits of the vegetation by means of them. My starting point is, therefore, the vegetation itself, and from the appearance of the vegetation it is possible, to a certain extent, to form an opinion as regards the ecological factors, in the same way as an opinion may be formed from these concerning the appearance and composition of the vegetation.

The marine algal vegetation divides itself into several zones as the Benthos does in fresh water. The divisions between the zones in the sea are very distinct: some species seem to be spot-bound or very sensitive to changes of level; other species may occur in two or several zones; but it depends especially, I think, on the quality of the water, the intensity of the light and, where there are tides, on the period of exposure (in the littoral zone).

By studying the vertical distribution of the species and associations, I have come to the conclusion that the marine algal vegetation may be divided into three zones almost parallel one with another: the Littoral Zone, the Semi-littoral Zone and the Sublittoral Zone.

The Littoral Zone understood in a more restricted sense is identical with the upper littoral zone and extends almost to the

low-water mark of neap-tide, and is exposed during each low-tide; the upper littoral zone is, then, the littoral zone proper, which doubtless corresponds exactly with Kolderup Rosenvinge's limitation of the littoral zone in Greenland, but not entirely with Børgesen's limitation of the littoral zone in the Færøes, as some of the Færøese littoral associations seem to belong to the next belt.

The semi-littoral zone extends from about the low-water mark of neap-tide to a depth of about 10 metres, and thus extends over the lower littoral zone, and even lower than that. In reality this zone comprises the lower littoral zone including stragglers below the low-water mark of spring-tide to a depth of 10 metres. That part of the zone lying in the lower littoral zone is laid bare at and about spring-tide, but is submerged at neap-tide.

The sublittoral zone extends from the low-water mark of spring-tide to the absolute depth-limit.

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There seems to me to be no reason for calling any part of the Benthos elittoral. Even if the 40-metre contour is a lower limit of growth in the case of several species, and is, approximately, the lower boundary of the *Laminaria*-community, yet the upper boundary of the red-algæ communities which extend further downwards than 40 metres lies much higher, and the 40-metre contour thus cuts straight through natural communities. It cannot, therefore, be considered the principal boundary as regards the whole of the constantly-submerged vegetation. Strömfelt (l. c.) is of the opinion that, possibly, elittoral vegetation does not exist on the coasts of Iceland. According to Kjellman the elittoral vegetation is extremely poor in species, and probably has a limited distribution everywhere in the northern seas. From what has been said above respecting the 40-metre line, and from a comparison with Greenland (Rosenvinge, 63) and the Færøes (Børgesen, 11 and 12), it is obvious that a division of the constantly-submerged vegetation at this depth-line is not quite natural in the northern seas. It is more correct, therefore, to do as Rosenvinge and Børgesen do, and to class the vegetation as sublittoral down to the absolute depth-limit.

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In the following I do not employ the term "region," which is now generally used to describe somewhat limited subdivisions of

the vegetation, as I have thought it better to designate the algal Benthos taken as a whole by this word, and to call it the "algal region."

I have also avoided the term "formation." The algal formations established by Kjellman and others are not real formations, but only associations (Warming, 72, p. 171), and the entire marine algal vegetation is given as a subformation of marine algæ (Halonereid; Warming, 72, p. 169). I do not think that the term "formation" should be used in connection with the algal region in any other sense than that in which it is used in connection with land vegetation. As the term "facies" cannot be used in English to denote a vegetation-unit (Warming, 72, p. 146, foot-note) I have avoided it.

I divide the vegetation in each of the three zones into associations, and where I think they are closely allied I combine them into communities.

Sometimes by the suffix "etum" is meant the subordinate part of an association, and sometimes a vegetation-unit which almost corresponds with an association.

## ACCOUNT OF THE MARINE ALGAL VEGETATION AND THE SEA-GRASS VEGETATION.

### A. The Marine Algal Vegetation.

#### a. The Littoral Zone.

##### aa. The Photophilous or strictly Littoral Communities.

1. The *Prasiola stipitata*-association.
2. The Community of Filiform Algæ.
3. The Community of Fucaceæ.  
+ The *Pelvetia-Fucus-spiralis*-belt.  
++ The *Fucus*-belt.

4. The *Enteromorpha*-association.
5. The *Acrosiphonia*-association.

##### bb. The Shade-vegetation.

6. The *Hildenbrandia*-association.
7. The *Rhodochorton*-association.

##### cc. The Vegetation of Tide-pools.

#### b. The Semi-littoral Zone.

8. The *Monostroma*-association.
9. The *Chorda*-association.

10. The Community of Rhodymenia.
11. The Polysiphonia urceolata-association.
12. The Community of Corallina.
13. The Crustaceous Alga-association.
- c. The Sublittoral Zone.
  14. The Community of Laminariaceæ.
  15. The Desmarestia-association.
  16. The Deep-water Community of Florideæ.
  17. The Lithothamnion-association.
  18. The Community of Crustaceous Algæ.
- B. The Sea-grass Vegetation.
  1. The Zostera-association.

## A. The Marine Algal Vegetation.

### a. The Littoral Zone.

The Littoral Communities. The littoral vegetation is composed of several communities. These are left dry during low-tide, with the exception of the pool-vegetation; but the period during which the different communities are left dry varies greatly. I am not prepared to state accurately the period of exposure, but I presume that the lowest littoral communities will be laid bare for about 1—2 hours under normal conditions, while the uppermost communities will be submerged for about one hour, and will be laid bare for about 11 hours. On exposed coasts the period of exposure is shortened by the beat of the waves. The ecological factors differ not a little in the uppermost and lowermost part of the littoral zone, and because of this difference the vegetation is divided into longitudinal belts along the coasts. The littoral vegetation falls naturally into three divisions: the light-loving or strictly littoral communities, the shade-loving communities, and the pool-vegetation. In the following description of the vegetation, the communities in each of the three zones are arranged as far as possible according to depth, and in such a way, that the uppermost come first and the lowest come last. This rule, however, cannot always be adhered to.

#### aa. The Photophilous or strictly Littoral Communities.

These communities are found in places in the littoral zone which are directly exposed to light during low-tide. They are composed of blue-green, green, brown and red algæ; the

brown algæ are found most abundantly, the green algæ come next, red algæ occur less frequently, and blue-green algæ are found in the smallest quantity. The substratum is either rock — solid rock or else talus of debris — or pebbles, or in many places consists of gravel, clay or mud. The perennial species prefer almost exclusively the rock-substratum; but they occur, though very seldom, on other substrata, and are then, as a rule, dispersed here and there on small stones, viz. on a gravel-clay soil at the head of the fjords. The annual, short-lived species also occur most frequently on a rock-substratum, but they also occur fairly frequently on the pebbles of the littoral zone.

### 1. The *Prasiola stipitata*-association.

This association extends furthest upwards and is found well developed on the rocks in several places round the coasts. It is usually almost on a level with the *Verrucaria-maura* belt and, upwards, sometimes approaches the outposts of the land-vegetation. At the highest water-level it is covered by the sea for a short period, or is, at least, washed by the breaking waves; but such high water occurs only rarely, and in normal conditions this association must, without doubt, be content with the spray from the waves during spring and summer. On less exposed coasts this association is, as a rule, sharply defined from the community of filiform algæ which exists below, but on a very exposed coast the boundary is more variable.

The dominant species in this association is the small, leaf-like *Prasiola stipitata*, which grows very socially upon the tops of flat rocks. As it has its distribution almost exclusively in this belt it seems natural to designate the association by its name. It is essentially adapted to live in the air, and is capable of withstanding desiccation well, which may be perceived, *inter alia*, by the fact that it does not seek clefts and crevices but grows on surfaces which are exposed to light, wind and weather. The density of the vegetation must also afford each individual some protection against desiccation. In spring and summer long periods must occur during which this association is not wetted by the sea, and, during summer drought, I have often seen *Prasiola stipitata* as dry as a bone upon the rocks. *Prasiola furfuracea* also occurs side by side with this species, but is rarer.

Species and varieties of species, such as *Enteromorpha intesti-*



*nalis* f. *micrococca* and *Rhizoclonium riparium*, which essentially belong to the lower belts, but can accommodate themselves to life in the air, are also included as members of this association. They are species which, owing to their structure or their manner of growth, are capable of enduring desiccation. *Enteromorpha intestinalis* f. *micrococca* has, as is well known, small cells, the walls of which are very thick, the inner walls, in particular, being highly thickened, serving possibly as reservoirs for water. It prefers fissures in the rocks, where, as a rule, it is less exposed than the species characteristic of the association. Sometimes, however, I have come across f. *micrococca* growing, like *Prasiola stipitata*, on flat rocks manured by birds, but then it had a different aspect and, at first sight, somewhat resembled *Prasiola*. *Rhizoclonium* also occurs in fissures, where, owing to its manner of growth — that is to say its pulvinate form — it is protected from desiccation during the long periods of drought. *Calothrix scopulorum* also occurs as a member of the *Prasiola*-association and forms *Calothriceta* of limited dimensions; the individuals are procumbent and are placed so closely together that the rock is completely covered, and thus they protect each other from desiccation. From a biological point of view, the manner of growth of this species, in the dry condition, is similar to that of the crustaceous algæ. *Enteromorpha intestinalis* f. *minima* also occurs in this community.

The species in this community grow, as a rule, in small, pure societies which form a narrow, though not a continuous belt along the coast. This belt is situated higher on exposed coasts than it is on those which are less exposed.

The *Prasiola*-association is undoubtedly commonly distributed in neighbouring countries, but the constituting species may be different. In Greenland (Rosenvinge, 63, p. 200) *Calothrix scopulorum*, *Ectocarpus maritimus*, and *Rhizoclonium riparium* occur only in the uppermost part of the littoral zone. This vegetation, however, scarcely corresponds with the *Prasiola*-association, but rather with that occurring below. In the Færøes, however, an exactly corresponding association is found, which Børgesen calls the *Chlorophyceæ*-formation (12, p. 712). The Færøese *Chlorophyceæ*-formation, however, appears to be more luxuriant and is composed, in part, of other species. A *Prasiola*-association (Foslie, 18, p. 127) similar to that of Iceland is evidently found in Finmark.



## 2. The Community of Filiform Algæ.

It is not easy to find a suitable name for this community. It is composed of several species which are all equally common and are all dominant to almost the same degree. As almost all the species are filiform and non-branching, it seems to me that the community may fitly be named in accordance with the form of the frond.

The community of filiform algæ forms a narrow belt, which is often continuous along fairly considerable stretches of the coast, at about the average limit of high water. The vertical height of the belt is inconsiderable, about one foot, but the breadth conforms somewhat to the slope of the coast, and may attain to 3—4 feet, or even more. This vegetation is very well developed on the face of vertical rocks, and the various associations of the community can be distinctly seen, one above the other, as parallel bands of varying colour. The species which occur most frequently are the following: —

*Ulothrix flacca*.

*Bangia fuscopurpurea*.

*Urospora mirabilis*.

*Porphyra umbilicalis* f. *typica*.

*Monostroma groenlandicum*.

These are all dominant species, and form extensive associations, of which some are pure and others mixed. Other species may also occur, but only in lesser quantities.

The *Ulothrix*-association, as a rule, reaches highest up the cliff. The principal species is *Ulothrix flacca*, which forms a distinct belt, extending rather far in a horizontal direction. On rock-walls, the filaments are often comparatively long, and are moved to and fro over the entire belt by the beat of the waves or the ripple of the sea at flood-tide; during the period of exposure they hang down, pressed closely against the face of the rocks. The outer filaments protect the underlying ones from desiccation during low-tide, and thus it happens rather frequently that the outer layer is dry while the protected layer — that nearest to the rocks — is moist. In this way the social growth of the plants protects them against desiccation (cf. Rosenvinge, 63, p. 201), at any rate under normal conditions, and so long as no exceptionally long periods of drought occur. It happens rather frequently, however, that the *Ulothrix*-vegetation becomes quite dry during low-tide. This is especially the case when the vegetation occurs on boulders in the littoral zone where, when the water subsides, the filaments radiate

from the highest point of the stone. Such a stone-surface is smooth and dries more quickly and completely than the uneven face of the rock. This vegetation appears to maintain itself well in spite of being completely dried up, day after day, during low-tide, — during the nocturnal low-tides, naturally, it is dried up to a much lesser extent. As a rule, such a dried-up *Ulothrix*-vegetation is so tightly adpressed to the surface of the stone that it can only be removed by being scraped away with a knife. Thus, owing to desiccation, it appears, from a biological point of view, to have assumed a crustaceous form, which evidently diminishes the evaporation from its surface.

The other species which occur in great quantities in this association, such as *Urospora mirabilis* and *Monostroma groenlandicum*, act biologically in a similar manner to *Ulothrix flacca*. Both these species are found fairly frequently growing among *Ulothrix flacca*; and as I think that these species may in several respects be comprehended in one biological unity, I consider them members of the same association, although they both occur in pure growths (*Urosporetum*, *Monostrometum*).

While *Ulothrix flacca* and *Urospora mirabilis* are commonly distributed, the distribution of *Monostroma groenlandicum* is more restricted, for this species can be reckoned as commonly distributed only in E. Iceland.

Of the species which are rare or of local occurrence, and which are reckoned in this association, the following may be mentioned: *Ulothrix pseudoflacca*, *Ulothrix consociata* var. *islandica* and *Urospora Hartzii*. In addition, *Enteromorpha intestinalis* f. *micrococca* and *Rhizoclonium* occur here as they do in the *Prasiola*-community.

Of these species *Ulothrix consociata* var. *islandica* requires to be described most fully. It is very social, and grows in cushion-like masses higher up, as a rule, than the other species of the association. It appears to be protected from desiccation both by its manner of growth and by the thickness of its cell-walls.

*Codiolum gregarium* I have found to be of very social growth, covering comparatively large stones as pure *Codiolela*. It is most nearly related to this association.

The structure of the frond in this association displays various peculiarities, which must be considered as being beneficial to the plant during the period of desiccation; for instance, the interior of the frond of *Monostroma groenlandicum* is filled with a gelatinous

mass. Rosenvinge (63, p. 201) has pointed out that this mass must be of importance as a reservoir for water during low-tide. *Ulothrix flacca* also has very thick cell-walls, especially in the fruit-bearing filaments (cf. Rosenvinge l. c.). The remaining species also are rather thick-walled.

Although the *Ulothrix*-association is distributed to an extraordinary extent, yet it cannot be expected to be found everywhere. It prefers that part of the littoral zone which is rocky and stony, and grows luxuriantly on a somewhat exposed coast, and even, indeed, on one which is very exposed. It also extends right into the fjords, if the nature of the shore is favourable to it.

The succession of the associations of filiform algae is seen most distinctly on vertical rocks on somewhat exposed coasts, where the *Ulothrix*-association appears uppermost; but where the substratum is uneven — a talus of debris or irregularly heaped-up fragments of rock — the zonal division of the community becomes less apparent, and it may then well happen that the *Bangia*-association extends above the *Ulothrix*-association.

The *Bangia*-association prefers the rocky part of the littoral zone, and vertical rock-walls in particular, and is only rarely found in the stony part of that zone; it occurs normally below the *Ulothrix*-association, but where the latter is absent the *Bangia*-association is not infrequently the algal vegetation which reachest highest. In many places it has an extremely wide horizontal distribution, and is often perceived at a considerable distance as a reddish-brown band in, and at the edge of, the water. This *Bangia*-belt may attain a considerable breadth, as much as three feet, and it often displays several shades of colour. Thus, in a less exposed spot facing the south, I have seen the uppermost part coloured green, the middle part brownish and the lowest part a fresh reddish-brown. This is certainly connected in some way with the long period of drought which, when the weather is calm or the wind blowing off the land, may well continue from neap-tide till about spring-tide. During the period of drought *Bangia* behaves somewhat similarly to *Ulothrix flacca*. The filaments are rather long, as long as 10 cm., and are very closely packed together; on vertical rocks they hang straight down during low-tide, and are, on the whole, protected by their structure and manner of growth from too severe desiccation, in the same way as has been mentioned in connection with the *Ulothrix*-association. The *Bangia*-belt is, as a

rule, distinctly separated from the *Porphyra*-association which exists below, but sometimes the two belts are concurrent, even over rather large areas.

The *Porphyra*-association is formed by *Porphyra umbilicalis* f. *typica*. It might be justifiable to incorporate this association in the *Bangia*-association, but I prefer to reckon it as a distinct association: partly on account of the difference in the form of its thallus, and partly because *Bangia* is confined to its narrow belt, while *Porphyra* occurs also in other associations in and below the *Fucus*-belt.

The *Porphyra*-association occurs on a rocky substratum. On vertical rock-faces it is very luxuriant, and then forms a continuous belt below the *Bangia*-association. Where the littoral zone has large fragments of rock, that is to say consists of a talus of debris, this species grows higher than any others upon the fragments at the water's edge. In such places no continuous belt is formed, but the species occurs in small scattered patches on the upper part of the blocks of stone. This patchy distribution of the vegetation may extend horizontally over either a small or a wide area, according to the form of the coast. The vertical height of the belt is always inconsiderable.

During the period of drought *Porphyra* hangs down on the vertical rock-faces, the thallus being repeatedly folded, according to its length; the individuals in the upper rows of the association often, to some extent, covering those below and thus, in some ways, recalling the behaviour of the above-mentioned filiform algæ; on the blocks of stone, also, the thallus is folded up in accordance with its length, and rests on the surface of the stone. The folding apparently serves to reduce evaporation during low-tide, as the evaporating surface is thereby diminished; the folding may well be of importance also in counteracting the effect of the light. As the folds of the thallus are produced while the water is subsiding, it is probable that some of this is retained between them, especially on a flat substratum; on a sloping or vertical substratum, however, the quantity of included water would be very small. This circumstance is probably of some importance, and has also been emphasized by Börgesen (12).

The *Porphyra*-association seems to maintain its freshness for a considerable time, and I saw it with its usual dark purple colour in several places in E. Iceland in the summer; but round about



Reykjavík, especially later in the summer, it frequently has a yellowish-brown tinge.

These associations, owing to local conditions, naturally are not found everywhere along the coasts. At times they are all present, and then generally in the succession here recorded; at other times only one or another is present. Thus, in some places, the upper limit of the marine algal vegetation is indicated by the *Ulothrix*-association, and in others by the *Bangia* or the *Porphyra* association; in places the entire community is absent, and then the boundary is marked by *Pelvetia*, *Fucus spiralis* or other *Fucaceæ*.

A comparison with the adjacent coasts shows that this community is found both in Greenland and in the Færøes though it does not behave in quite the same manner in both places. In Greenland a *Monostroma groenlandicum*-association is found which is composed of *Monostroma groenlandicum*, *Ulothrix flacca* and *Urospora mirabilis*, all intermixed with *Bangia fuscopurpurea*. This association occurs in the middle part of the littoral zone. A *Porphyra umbilicalis*-association occurs also in the upper part of the littoral zone. Thus, the same species occur in Greenland as in Iceland, although possibly they are not present in the same numerical proportion. But one great difference exists, namely that the Greenland community is found in the middle of the littoral zone, while the Iceland community is found much higher up. There is a similar difference in the occurrence of the *Porphyra*; as it is found in fissures of the rocks in the upper littoral zone in Greenland, while in Iceland it grows upon the surface of the rocks. This difference is probably due to a difference in the climate.

It is possible that the same community (Börjesen, 12, pp. 716, 719) may be found at an even greater height in the Færøes than in Iceland. In the Færøes the species are only partially similar, because *Monostroma groenlandicum* is wholly absent, and *Ulothrix flacca* does not seem to play such an important part there as it does in Iceland. The community of filiform algæ is, in all probability, common along the coast of Norway (Foslie, 18; Börjesen, 12, pp. 719—720; Boye, 10, p. 20).

### 3. The Community of *Fucaceæ*.

This community is the dominant one in the littoral zone and comprises six associations, of which the first two, the *Pelvetia*-association and the *Fucus spiralis*-association, are more closely



connected with each other than they are with the remaining associations, which also are mutually very closely connected. In this way the community may be divided into two belts, of which the first comprises the two first-mentioned associations, and the second the remaining four. The *Pelvetia-Fucus-spiralis*-belt is narrow. It is situated in the upper part of the littoral zone, at, and just below, lowest high-water mark, i. e. flood-mark at neap-tide. It has only one layer of vegetation, as there is no undergrowth worth mentioning, and it is entirely devoid of epiphytes; it is submerged in normal conditions for a very short time.

The second, the *Fucus*-belt is broad; it occurs in the lower part of the upper littoral zone, just above low-water mark of neap-tide. The vegetation occurs in two, and sometimes in three, layers and epiphytes are present in abundance. The vegetation is submerged much longer than in the first belt. Thus, these two belts differ so greatly that they cannot be treated together.

#### The *Pelvetia-Fucus-spiralis*-belt.

This belt is of common occurrence, and its vegetation is luxuriant in S. and SW. Iceland, but in the other parts of the country is sparse and devoid of *Pelvetia*. This belt is not continuous except along short distances, and its vertical height is inconsiderable; but the breadth may sometimes be fairly considerable, especially on very gently sloping coasts. It grows on rocky coasts, and in places where these consist of a talus of debris the vegetation is distributed in patches which is a natural consequence of the surface, the limit of the association being rather sharply defined downwards. *Pelvetia* and *Fucus spiralis* do not grow intermixed, but occur in two pure and distinct associations. They grow luxuriantly on exposed coasts; in the most exposed parts of the coast, however, they seem to recede. Thus, this belt was either absent from, or was poorly represented on the most exposed points at the extremity of Snæfellsnes and of the Vestmannaeyjar and at the extreme end of Reyðarfjörður; but there occurred in its place surf-forms of *Fucus inflatus* (f. *exposita* and f. *dendroides*).

The *Pelvetia*-association (Fig. 3) always occurs highest of all. As already mentioned it is found in S. and SW. Iceland only, but there it occurs in great abundance in many places; in some places its vegetation is poor, and sometimes only a few scattered individuals are found. This is more particularly the case in places where *Pelvetia*

appears to have extended too high upwards, and where, when the weather is calm, it is not wetted daily by the sea at and about neap-tide. On a warm summer's day *Pelvetia* can become so dry in such places that, when gathered, it needs no further drying — the same may also be the case with *Fucus spiralis*. The individuals of *Pelvetia* which grow at that height, i. e. sometimes right up in the *Verrucaria maura*-belt, are usually very small (about 2 cm. in height) and occur closely pressed to the rock; then they are often



Fig. 3. *Pelvetia canaliculata* above, *Fucus spiralis* below. Illustration of a typical *Pelvetia*-*Fucus-spiralis*-community. Reykjavík, Aug. 13, 1909. (From phot. by Hesselbo.)

found especially in crevices, and the new fronds may bear a surprisingly close resemblance to a rosette. Lower down, where the vegetation is luxuriant, the plants are about 8 cm. in height. *Pelvetia* is the smallest of the *Fucaceæ* on these coasts; it differs from the others not only by its small size, but also by its lighter, yellowish-brown colour, and its channelled frond, etc. The channelled frond must be useful to a plant which is so exposed to the desiccating action of the air as is the case with *Pelvetia*, because, by reason of their being rolled, the under-side of the fronds is less exposed to wind and weather.

It is characteristic of the zonal division of the *Fucaceæ* on the

coast that the smallest species (*Pelvetia*, *Fucus spiralis*) are arranged in a separate uppermost belt, while the larger species are arranged in belts lower down, and the largest species (f. *inflatus*, if the large broad-fronded forms are included) occurs lowest of all.

The *Fucus spiralis*-association (Fig. 4) is more luxuriantly developed than the *Pelvetia*-association and occurs just below it. On flat or very gently sloping rocks this association forms a comparatively broad belt, but on a steep coast only a narrow one. Its relation



Fig. 4. *Fucus spiralis*. Part of a luxuriant *Fucus spiralis*-vegetation below the *Pelvetia*-association. Reykjavik, Aug. 13. 1909. (From phot. by Hesselbo.)

to exposed coasts has already been discussed. It may happen with *Fucus spiralis*, as with *Pelvetia*, that it extends to so great a height that at times it is not wetted daily by the sea. In such a case the individuals are as a rule smaller, and are often rather strongly spirally twisted; they may be found lying quite dried up on the rocks, apparently without being damaged thereby. The twisting of the fronds may possibly result from the drying process.

This belt is, as a rule, somewhat sharply defined from the *Fucus vesiculosus*-belt situated below. Although it does not always happen that there is any distance worth mentioning between *F. spiralis* and the upper outposts of the *Fucus vesiculosus*-association, yet the boundary is almost always sufficiently distinct.



This belt behaves similarly in the Færøes (Börgesen, 12, p. 744). Both Boye (10) and Hansteen (25) mention a *Pelvetia*-formation from western Norway without mentioning *Fucus spiralis*. In Finmark *Fucus spiralis* has the same manner of growth as in Iceland (Foslie, 18, p. 66).

### The *Fucus*-belt.

The four associations which belong to this belt are the most extensive in the littoral zone and three of them are found everywhere on rocky coasts. The breadth of the belt naturally is dependent on the degree of the declivity of the coast in addition to the nature of the substratum. This belt occurs everywhere along the coast, but it is not luxuriant to the same degree everywhere. Its vegetation is so dense that the bottom is entirely covered, or almost so, by the *Fucus* plants which during low-tide partly lie prostrate upon the rocks and partly hang on them; seen from a distance it appears as a brown-coloured belt of varying width along the coast. These associations are usually found on a rocky substratum, but they may also occur on a fairly firm gravelly bottom; the latter is especially the case at the head of the fjords. In such places their vegetation is poor and the species grow scattered, attached especially to small stones which are somewhat firmly embedded in the gravelly bottom. *Fucus* plants are also found scattered on wood-work, for instance, on wooden piles. On the whole the species of *Fucus* require a stable substratum. The dominant species are the following: —

*Fucus vesiculosus*.

*Fucus inflatus*.

*Ascophyllum nodosum*.

*Fucus serratus*.

The first three species are common and grow very luxuriantly along the coast; *Fucus serratus*, on the other hand, was found only in a few places in S. and SW. Iceland; in Hafnarfjörður it grew very socially, while in the Vestmannaeyjar it had a more scattered growth.

The individuals of these species form pure associations which usually occur in regular succession: *Fucus vesiculosus* growing uppermost, *Ascophyllum* in the middle and *Fucus inflatus* (and *Fucus serratus*) lowest of all. This succession is distinctly observable in places where the bottom is flat and gently sloping. But where the bottom is uneven — a talus of debris — the divisions between the belts are less regular, but can, as a rule, be discerned. It does not, however, follow that the associations always occur quite regularly;

the species being rather frequently found intermingled; the *Ascophyllum*-association, in particular, does not appear to be as spot-

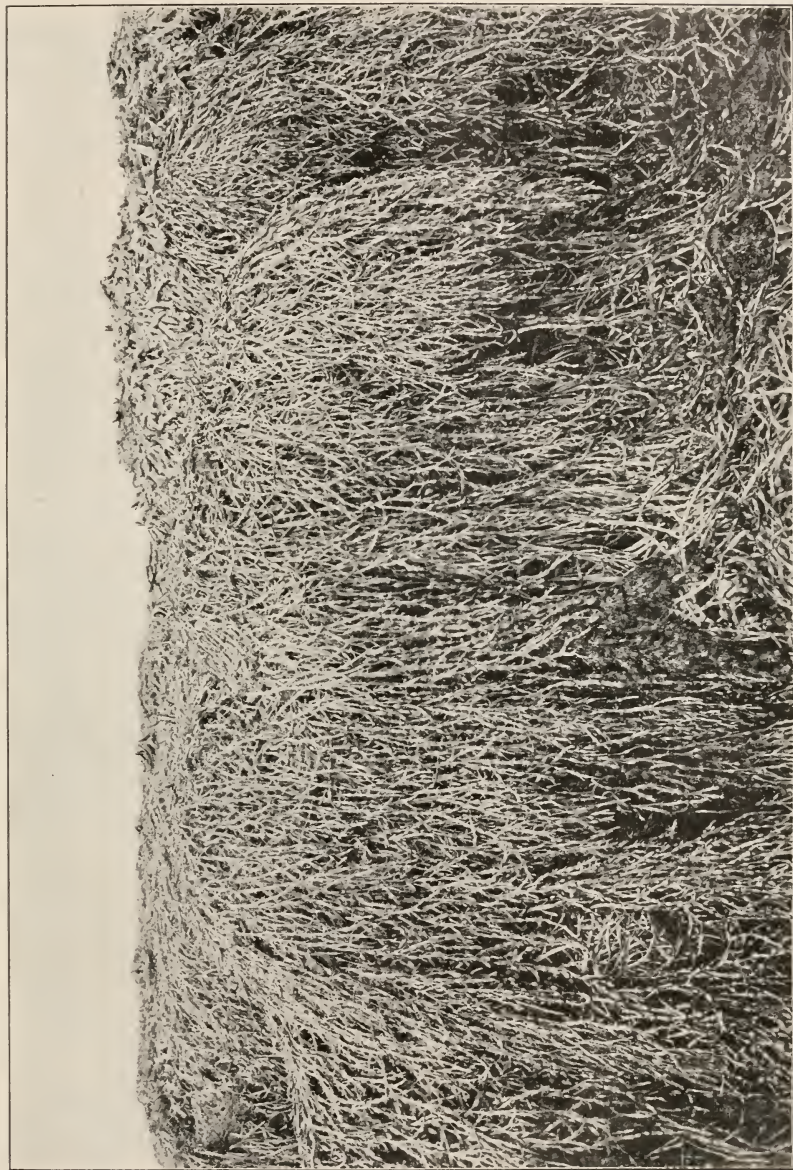


Fig. 5. *Ascophyllum nodosum*, with *Polysiphonia fastigiata* as epiphyte, hanging down on the rocks, Reykjavík, Aug. 13. 1909.  
(From phot. by Hesselbo.)

bound as the others. It generally occurs somewhat below the middle of the area occupied by the community, but may occur also higher up, even at the very top. It is, however, a fairly constant fact that



*Fucus vesiculosus* grows highest and *F. inflatus* lowest. How the species behave when left dry is mentioned in connection with each association.

The *Fucus vesiculosus*-association, as already mentioned, is uppermost and often borders closely on that of *Fucus spiralis*. It varies extremely in extent, according to the character of the coast. The breadth may vary from about one foot on vertical rocks to several fathoms on a gently sloping coast.

*Fucus vesiculosus* extends right into the innermost part of the fjords, which is generally considered a protected coast; if there is a favourable substratum there, its growth may be fairly luxuriant. It also grows very luxuriantly on slightly exposed coasts, i. e. where a landward wind is sometimes both frequent and tempestuous, but where breakers are extremely rare. If the exposure is increased, it seems that *F. vesiculosus* not only decreases in number of individuals but also seeks for shelter between the rocks. Then, gradually, it retreats lower into the littoral zone, and *Ascophyllum*, which is evidently better able to withstand the heavy seas, advances. This is seen very distinctly at Reykjavík, where the coast must be considered somewhat exposed, because the south-west, west, and north winds are frequently stormy and occasion heavy seas. If we take a bay which is bounded by a rocky promontory, we see at the head of it a luxuriant *Fucus vesiculosus*-association; this extends out upon the promontory, growing gradually narrower as it extends outwards; in the vicinity of the point itself, the alga has commenced to seek for shelter, and at the extreme end of the point it has disappeared and *Ascophyllum* has occupied its place, and then *Fucus vesiculosus* is either found not at all or only a few individuals of it occur high up in the *Ascophyllum*-belt. What is here seen on a small scale is repeated on a larger scale on proceeding from the head of the fjord outwards to the extreme point of the peninsulas. Thus, *Fucus vesiculosus* was not observed on exposed points at Øndverðarnes (the extreme point of Snæfellsnes), while *Ascophyllum* and, naturally, *Fucus inflatus* also, were found in abundance. On the most exposed points of the Vestmannaeyjar *Fucus vesiculosus* was also absent, while both of the others occurred plentifully.<sup>1</sup> Thus, *Fucus vesiculosus* behaves in Iceland precisely as it does in the Færøes (Börgesen, 12, 11).

<sup>1</sup> Strömfelt (70) records *Ascophyllum* as growing above *Fucus vesiculosus* at Hólmanes in E. Iceland.

Generally this species forms a pure association, but yet, sometimes, it and *Ascophyllum* can grow intermixed.<sup>1</sup> It is always submerged at high-water, but seems well able to withstand desiccation at low-water, when however the upper side of the frond dries up considerably, especially on rocks which face the sun, and may then — and this is true of *Fucus inflatus* also — be bent upwards, or even slightly distorted, at the apex, though never to the same extent as is the case with *Fucus spiralis*. When such a branch is lifted up, it can be seen that the under side is moist, even on a warm summer's day. During low-tide the *Fucus* plants lie prostrate on the rock, one plant overlying the other, or one branch of the frond covering the other, and in this way some water is retained amongst the plants.

Naturally, this applies also to the members of the other associations in the *Fucus*-belt. Those individuals which hang freely from the rocks are exposed more than others to desiccation.

The *Ascophyllum*-association differs from the other associations in its light-brown colour, and, in addition, by the occurrence of *Polysiphonia fastigiata*, which grows very luxuriantly on it in S. and SW. Iceland; it is often somewhat singular to see the light-yellow *Ascophyllum*-belt with the numerous dark reddish-brown patches of *Polysiphonia*.

So far as the behaviour of the species during exposure to the beat of the waves is concerned I must refer to the above-mentioned remarks, and can only add that at times it may also occur in the most exposed places, but no longer in the uppermost belt. Here it gives place to the surf-forms of *Fucus inflatus* (f. *exposita*, f. *dendroides*), which form a narrow belt at the upper boundary of the *Fucus*-belt. *Ascophyllum* occurs, then, between this and the real *Fucus inflatus*-belt, which retains its usual position. In a few places, however, on the most exposed points, *Fucus inflatus* only is found.

The *Fucus inflatus*-association. When exposed, this species behaves conversely to *Fucus vesiculosus* and grows most luxuriantly on exposed coasts. Thus, it behaves in Iceland as it does in Greenland (Rosenvinge, 63) and in the Færøes (Börgesen, 12). In Iceland, as in other places, the species varies extremely and must be considered very capable of adapting itself to varying circumstances, especially as regards exposure. The association can — in accordance with the exposure — be divided into three belts: — The Surf-belt, the Wave-belt, and the Calm-belt.

<sup>1</sup> The epiphyte-vegetation is mentioned subsequently.

The Surf-belt, as previously stated, occurs at the upper boundary of the *Fucus*-association on rocky coasts which are very much exposed. I have seen such a belt at Øndverðarnes in SW. Iceland, in the Vestmannaeyjar in S. Iceland and at Vattarnes in E. Iceland. Strömfelt (70) has noticed a similar belt on Seley in E. Iceland. It will probably be found, on further investigation, that the surf-belt is far more widely distributed along the coasts than is recorded above. As a rule, the individuals in this belt are of low growth; the frond is leathery, and very thick in proportion below, and rounded, but tapering evenly upwards and becoming thinner: above, it is often excessively branched. The height of the individuals varies to some extent, f. *dendroides* is the highest, while f. *exposita* attains only an insignificant height (5—9 cm.). A similar surf-belt occurs in the Færøes (Börgesen, 12), although the vegetation is possibly more luxuriant there than in Iceland.

The Wave-belt (Fig. 6) comprises the ordinary *Fucus inflatus*-belt. As a rule, it is exposed to the movement of the waves, a movement which is often very violent indeed; more rarely it is exposed directly to the breakers. Here the species occurs in its typical form which shows a considerable variation in the breadth and consistency of the thallus. In very exposed places the branches of the frond are comparatively long and narrow and leathery, but where the movement of the waves is less felt, the frond is usually broader. The vegetation of this belt is generally very luxuriant, and covers the substratum entirely. Often, however, the vegetation occurs in patches, owing to the surface-features of the shore. Such a mode of occurrence is met with, for instance, where the shore is a wild talus of debris consisting of large scattered blocks of stone, or where the solid rock has a similarly uneven surface owing to erosion by the sea. There a belt is formed around each block of stone, while the hollows between them are occupied by semi-littoral or sublittoral vegetation, or by stragglers from these zones.

The Calm Belt is lowest of all, often at the boundary between the constantly submerged and the lower littoral vegetation, and sometimes forms small offshoots of vegetation<sup>1</sup> below that boundary. Here the movement of the waves is least felt, and the frond of the

<sup>1</sup> The species varies from the principal form to two kinds of dwarf-forms — a small "surf-form" of tough texture, and a small "pool-form" of delicate texture. The pool-form-association (*F. inflatus* f. *linearis*) may be regarded as the fourth belt, which should then be termed the Delicate Belt (see under The Vegetation of Tide-Pools, p. 125).



plants is also usually broader. In this belt the broad forms are to be found; they may occur both with and without air-bladders. This belt is as a rule poorly developed, and is often non-continuous. Within Hvammsfjörður, in bays protected from the surf, but where current-movements are felt to a certain extent, I have observed, below low-water mark, semi-littoral stragglers from the *Fucus*-community (i. e. from the *Fucus inflatus*-association). In a similar locality I saw *Ascophyllum* occurring semi-littorally.



Fig. 6. *Fucus inflatus* (sterile plants) lying prostrate upon the rocks. Above, hanging *Ascophyllum*. Reykjavík, Aug. 13, 1909. (From phot. by Hesselbo.)

The *Fucus serratus*-association was especially luxuriant in Hafnarfjörður on both sides of the fjord, some distance from the head of it, and occurred lowest of all in the *Fucaceæ*-community. In the Vestmannaeyjar the species grew scattered here and there, but was not found in the most exposed places. Sometimes on exposed coasts it was found growing in pools in the middle of the littoral zone.

The Epiphytes and Intermixed Species of the *Fucus*-belt. As is well known, an abundance of epiphytic vegetation exists in the *Fucus*-belt, at any rate at times. Many of the species grow socially and often occur in such quantities, that they set their stamp upon the vegetation. These species may be divided into those

which grow exclusively, or by preference, on the *Fucaceæ*, and those which occur as frequently on other substrata and must consequently be considered chance visitors.

Only one single species, *Polysiphonia fastigiata*, is exclusively confined to the *Fucus*-belt (Fig. 7). It is well known that this species grows only on *Ascophyllum nodosum*, into the frond of which it puts its rhizoids,<sup>1</sup> although its distribution does not coincide entirely with that of the latter. While *Ascophyllum* is common everywhere along the coast of Iceland, *Polysiphonia fastigiata* is common only in S. and SW. Iceland; it has been found, also, in a single place in NW. Iceland. Thus it keeps to the warmer parts of the sea off the coasts of Iceland, but even within this area it may be absent from coasts where the sea-water mixes abundantly with the fresh water. It did not occur for instance at Borgarnes, nor on the nearest islands, although *Ascophyllum* occurred in great quantities together with *Fucus vesiculosus* and *Fucus inflatus*. There the sea-water is freely mixed with water from the large glacier-torrent of Hvítá in Borgarfjörður. *Polysiphonia fastigiata* does not seem able to endure such water, but further out, along the fjord, where the water becomes more saline, it grows in the ordinary manner.

Of those species which grow by preference on *Fucaceæ*, *Elachista fucicola* and *Ulvella fucicola* may be mentioned. The first of these is the most important and often occurs in wonderful abundance, *Ulvella* forms a much less important part of the vegetation, more especially on account of its minute size.

Besides these two, other species frequently occur which just as often, or even more often, grow on other substrata. Of these *Pyraliella littoralis* plays a very important part in the vegetation, especially in the spring; then it sometimes occurs in such quantities that it almost covers large stretches of the coast. *Ulothrix flacca* also frequently occurs in great abundance, as may also be the case with *Isthmoplea sphaerophora*. In spring and early summer *Ectocarpus tomentosus* and *Ectocarpus fasciculatus* are found growing together socially on *Fucus inflatus* (both of them in S. and SW. Iceland). *Ectocarpus confervoides* is also a rather frequent epiphyte. In addition, *Monostroma* and *Enteromorpha intestinalis* may be mentioned, on which, again, epiphytes can grow (as for instance *Chantransia*-species); also *Ulothrix pseudoflacca*, *Acrosiphonia*, *Ceramium rubrum*, *Ralfsia verrucosa*, *Conchocelis rosea*, *Porphyra umbilicalis* and others.

<sup>1</sup> Gertrud Tobler-Wolff, in Beihefte z. Botan. Centralbl., Bd. 24, 2. Abt., 1909.



It is usually the case that it is the older parts of the fronds which are most covered by epiphytes; this agrees well with the fact that the older fronds have a rougher surface than have the younger ones, and therefore retain the spores better. The epiphytes

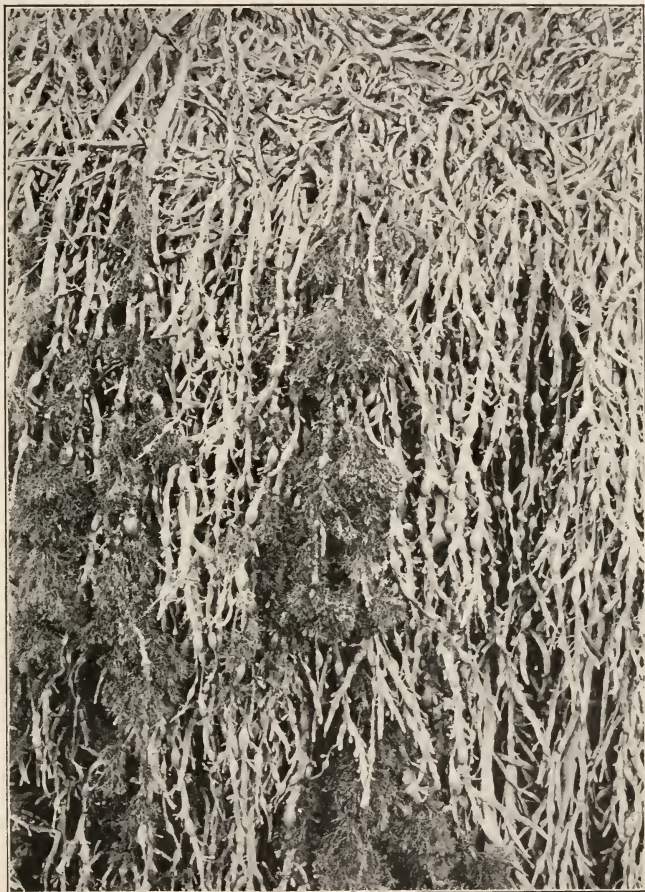


Fig. 7. *Polysiphonia fastigiata* on *Ascophyllum* which is hanging on the face of the rock.  
Reykjavík, Aug. 13, 1909. (From phot. by Hesselbo.)

on the *Fucaceæ* do not appear to arrange themselves in strata as do the *Laminaria*-epiphytes.

The intermingled species do not play any special rôle in the *Fucus*-belt, as regards the vegetation; they consist partly of species which grow on the *Fucaceæ* and partly of species which ordinarily grow outside the *Fucus*-belt. Of these species the following may be mentioned: —

<i>Monostroma</i> Grevillei.	<i>Cladophora</i> rupestris.
<i>Ulothrix</i> flacca.	<i>Acrosiphonia</i> .
<i>Monostroma</i> groenlandicum.	<i>Enteromorpha</i> intestinalis.
<i>Pylaiella</i> littoralis.	<i>Porphyra</i> umbilicalis.
<i>Chordaria</i> flagelliformis.	<i>Chaetomorpha</i> tortuosa.

The Under-vegetation. This is found commonly distributed, and varies considerably, both as regards luxuriance and the species composing it. The luxuriance seems to increase with the degree of exposure (except perhaps in the most exposed places), and then the composition of the species is also changed, as species which primarily belong to a lower belt extend higher up, probably on account of the frequent movements of the sea which cause the desiccation-period to last but a short time. The undergrowth must be regarded as a kind of shade-vegetation; during low-tide it is completely covered by the *Fucaceæ*, and at high-water the intensity of the light is also subdued by them, as they float on, or rise with, the water, and are moved backwards and forwards by its ripples. The greater part of the species of the undergrowth do not occur at the height of the *Fucus*-belt in places open to the light, but occur frequently and abundantly in shaded localities, although these may be found at the upper boundary of the *Fucus*-belt as, for instance, in depressions in the talus of debris, upon the under side of overhanging blocks of stone. This vegetation may therefore be justly termed the shade-vegetation of the littoral zone. The species are normally developed and cannot be compared with the shade-forms of light-plants belonging to the land-vegetation. On the other hand, the shade-vegetation of the littoral zone actually corresponds with the shade-vegetation of the land, such as the fern-vegetation and the liverwort-vegetation in the lava-fissures.

The under-vegetation belongs in part to the shade-vegetation (see p. 123) and is divided into several associations; here it is dealt with under the *Fucus*-belt as its strictly littoral distribution almost coincides with that of the latter, and it is just as dependent on the upper-vegetation, or even more so, as is the undergrowth in a coppice. As regards the relation between the upper-vegetation and the undergrowth in the *Fucus*-belt the main advantage is, I think with the undergrowth; although during low-tide, the upper-vegetation may gain some advantage from the fact that the layer of living plants under it retains more water than does the bare surface of the rock.

The following species of the under-vegetation occur in such quantities that they form associations of considerable extent which are usually pure, but may sometimes be mixed: —

*Hildenbrandia rosea*.<sup>1</sup>

*Rhodochorton Rothii*.

*Sphacelaria britannica*.

*Polysiphonia urceolata*.

*Gigartina mamillosa*.

*Ceramium rubrum*.

*Callithamnion Arbuscula*.

The *Hildenbrandia*-association is most extensively distributed, and is found everywhere along the coasts. It usually occurs as a pure association, though, in many places, *Verrucaria mucosa* is intermingled with it. *Hildenbrandia* may also occur at the same height outside the *Fucus*-covering, but is then — if the light is not subdued by other plants or projecting rocks — usually of a darker colour.

The *Rhodochorton*-association often covers extensive areas, like a dense, red carpet of felt. Most often it is pure, and appears, as far as its littoral distribution is concerned, to be confined mainly to the shady parts of the littoral zone. A few of the other shade-species may be found intermingled with it in small numbers, which fact is of minor importance, whereas the occurrence of the epiphyte *Pleurocapsa amethystea* is of great importance, as this species is found only on *Rhodochorton Rothii*.

*R. Rothii* does not occur below the *Fucus*-belt of the littoral zone until it occurs again at a considerable depth on *Laminaria* stems; thus it is found in two distant belts: the shade-belt of the littoral zone and the *Laminaria*-belt.

A *Sphacelarietum* (*S. britannica*) occurs almost quite pure in many places over rather large surfaces; it forms a dense covering on the rock as does *R. Rothii*. *Sphacelaria radicans*, *Polysiphonia urceolata* and *Rhodochorton Rothii* occur intermingled.

*Polysiphonietum*. *P. urceolata* occurs in a similar manner, covering rather large surfaces of rock. In places where the species forms extensive mats, it is usually very low in growth, yet always considerably higher than *Rhodochorton Rothii*. A thin layer of fine clay may often be seen to have accumulated between its basal parts.

A *Gigartinetum* occurs as under-vegetation, especially in more exposed places, and is then generally found in the lowest part of the *Fucus*-belt or in the *Fucus inflatus*-association; it is a direct continuation upwards of the *Gigartina*-association below.

<sup>1</sup> Arranged in accordance with the frequency, the most frequent coming first.



In addition Ceramieta formed by *Ceramium rubrum*, and Calithamnioneta formed by *Callithamnion Arbuscula*, occur distributed in patches, especially in the Vestmannaeyjar.

The following species, growing in a more scattered manner, occur also in the under-vegetation of the *Fucus*-belt: —

Delesseria alata.  
Lithothamnion.

Plumaria elegans.

The species of the under-vegetation thus belong principally to the red algæ; only two species being brown, one blue-green and one being a lichen. The majority of the species belong to the shade-vegetation of the littoral zone.

#### 4. The Enteromorpha-association.

Of the *Enteromorpha*-species *E. intestinalis* is the most common and the most variable. The variability, no doubt, principally depends upon local conditions, possibly also, on the age of the species. The typical form is extremely common in the upper littoral zone, but occurs most luxuriantly in the water-filled depressions. As a rule, the plants have a social growth, although they rarely cover large areas. *E. prolifera* and *E. clathrata*, on the other hand, occur in such abundance that it might be justifiable to speak of an association formed of branching *Enteromorphas*. These species are found in greatest abundance in the middle littoral zone, often in empty depressions in the lower part of the *Fucus*-belt proper, and may sometimes extend beyond the boundary of the lower littoral zone, where they then encounter semi-littoral associations, for example, *Dictyosiphonietum*, *Chordarietum* and others. While the typical form of *E. intestinalis* seems to flourish during the spring, the branching forms *E. prolifera* and *E. clathrata* are noticeable in the summer. I have known these two species to occur predominantly in June, July and August on the same substratum upon which *Urospora Wormskioldii* was growing in great quantities in the month of May.

*Enteromorpha Linza* is also a summer species, and, although it forms in several places pure *Enteromorphaeta* of lesser extent, plays only an inferior rôle in the *Enteromorpha*-association.

In E. Iceland, on the point between Seydisfjörður and Loðmundarfjörður, at the height of the lower part of the *Fucus*-belt and a little lower, I found a *Chlorophyceæ*-vegetation which must be considered to belong most nearly to this association. A *Monostro-*

metum of *Monostroma groenlandicum* was here found in abundance, often entirely covering the boulders and occurring on them, like *U. flacca*, closely pressed to the stone-surface with a radiating arrangement. In addition, an abundance of *E. intestinalis* f. *compressa* and a few *Ulothrix flacca* were found. A little lower down, a *Urosporetum* (*U. Wormskioldii*) occurred, which can scarcely be separated from this association; it seemed to form a connecting link with the semi-littoral communities.

*Cladophora gracilis* occurred intermingled in the *E. clathrata*-association, yet without playing any important rôle in the vegetation.

A similar association, especially an *Enteromorphetum* of *E. intestinalis*, is, beyond doubt, very common in other countries. It seems to be more poorly developed in Greenland (Rosenvinge, 63, p. 205) than in Iceland; in the Færøes (Börgesen, 12, pp. 714, 715), on the other hand, the *Enteromorpha intestinalis*-vegetation seems to be more luxuriant than in Iceland.

### 5. The *Acrosiphonia*-association.

This association consists of decidedly filiform, much branched algæ, which grow very socially. During the period of desiccation they retain the water as a sponge retains it. This circumstance is mentioned with regard to some of these species by Rosenvinge (63, p. 202), who says of *Cladophora arcta* (= *Acrosiphonia incurva*, cf. Jónsson, 32, p. 43) that in Greenland it behaves during low-tide like a sponge saturated with water.<sup>1</sup>

The principal species in this association are *Acrosiphonia albescentis* and *A. incurva*. They form individually, pure *Acrosiphonieta* in the upper and lower littoral zones, where they cover flat stones with a densely matted vegetation. On flat rocks the association may be somewhat widely distributed, in other places it has more the character of scattered *Acrosiphonieta*. The density of the vegetation is due to the structure of these species. As the basal part of the principal axis is too weak to carry the plant when its branch-system has developed, lateral rhizoids, which slope downwards, are developed at an early stage from the principal axis itself and from the lower branches. These rhizoids often form creeping filaments from which arise erect shoots, which can be detached from the parent-plant and thus become independent individuals. The principal

<sup>1</sup> Possibly this is the case in an even higher degree with *Callithamnion Arbuscula* (cf. Börgesen, 12, p. 726).



axis dies away from below and in this way branches, or systems of branches, with well developed rhizoids are detached from the parent-plant and become independent individuals (cf. Jónsson, 32). The rhizoids of one individual become entangled with those of others, and in this way the basal parts of the entire vegetation become matted together. In addition to this, the lower branches are hook-shaped, or bent downwards and outwards; thus it easily happens that they are entangled between the branches of other individuals, which further increases the matted condition. The upper branches are directed obliquely upwards, without being entangled with the branches of other individuals.

An *A. albescens*-association occurs everywhere along the coasts, but on very exposed coasts the species generally grows dispersed. Here it occurs in separate tufts which are, no doubt, composed of several individuals, densely matted together below, but branching upwards in various clusters, which are themselves densely matted together by their hook-shaped branches; the branch-systems above are, as usual, free. These characteristically matted branch-clusters are probably an effect of the heavy beat of the waves; the matted *Acrosiphonia* "tufts" will not be able to resist the force of the waves and, even at an early stage, will become divided into very densely matted branch-clusters.

*Acrosiphonia albescens* occurs both in the upper and the lower littoral zone, while *A. incurva* belongs to the lower littoral zone, but yet also extends upwards into the pools of the upper littoral zone, and below low-water mark.

Spongomorphetum. *Spongomorpha vernalis* grows very socially, but never forms such a dense vegetation as does *Acrosiphonia*, although it is sufficiently dense to characterize the spot. The species has been found in only a few places; it occurs in abundance at Gróttu, where it grows both on a stony substratum and also as epiphytic vegetation in the *Corallina-Gigartina*-belt and in the *Poly-siphonia urceolata*-association of the lower littoral zone.

A Cladophoretum formed of *Cladophora sericea* f. (see under Tide-Pools) also belongs to this association. It forms a densely matted belt in pools high up in the upper littoral zone. As a rule it follows the edge of the water round the entire pool.

*Cladophora rupestris* ought also to be considered to belong to the *Acrosiphonia*-association.

An association similar to the *Acrosiphonia*-association is, no

doubt, very common in adjacent lands. During low-tide the uppermost free branches appear to be more exposed to desiccation and possible death in Greenland than in Iceland; in the latter place it occurs rather frequently. Both in Greenland (Rosenvinge, 63) and in the Farøes (Börgesen, 11, 12) the *Acrosiphonia*-association is well represented.

#### bb. The Shade-vegetation.

To this vegetation are referred certain littoral associations which occur exclusively in shady places. The shade is produced by the light being subdued both by a covering of living plants and by projecting blocks of stones. Thus the greater part of the under-vegetation-associations of the *Fucus*-belt mentioned above belong to the shade-vegetation. In addition, the shade-vegetation grows, as already mentioned, on the under side of overhanging rocks — on their in-sloping sides. The vegetation is divided into several associations which have already been mentioned in connection with the under-vegetation of the *Fucus*-belt (cf. p. 118).

The frond differs in form and structure in the various species of this vegetation. It is a feature common to the whole of the shade-vegetation to be low and dense in growth. The frond of *Hildenbrandia* is a crust which covers the rocks; the others are finely branching; some, as *Sphacelaria* and *Polysiphonia* are bush-like and are richly and finely branched; *Rhodochorton* has a similar mode of branching, but to a considerably less degree. These three species often propagate vegetatively by means of runners, which increases the density of the vegetation. *Plumaria* is closely and distichously branched; it is tightly adpressed to the surface of the stones during the time of low-tide and retains much water between its branches, considered from a biological point of view it might almost be regarded as leaf-like during the period of desiccation.

6. The *Hildenbrandia*-association belongs almost exclusively to the under-vegetation of the *Fucus*-belt, and of the shady localities in the littoral zone (see above, p. 118).

7. In shady places the *Rhodochorton*-association, the *Sphacelarietum britannici*, and the *Polysiphonietum urceolatae* behave in a similar manner outside the *Fucus*-belt as they do within it (see above). They may occur either as pure as-

sociations, and are then dominant here and there in patches, or the species may be found intermingled with each other. Besides these associations a *Plumarietum*, consisting exclusively of *Plumaria elegans*, is found in many places. This association is darker in colour than the other red-algæ associations of shady places; it occurs frequently in S. and SW. Iceland. Intermixed in it occur *Callithamnion scopulorum* and *Chantransia virgatula*.

*Rhodochorton Rothii* is sometimes found high up in the littoral zone on flat rock-surfaces exposed to the light and to the beat of the waves, but then it grows in small globular cushions (*f. globosa*). Consequently, this globetum of *Rhodochorton Rothii* does not belong exclusively to the shade-vegetation.

On flat surfaces in the shade the usual arrangement is that the decided shade-associations occur at the bottom, where the light is feeblest, e. g. the *Sphacelarietum*, *Rhodochortonetum*, *Polysiphonietum*, *Plumarietum*; at the top, where the illumination is stronger, light-loving species occur, e. g. *Pylaiella*, *Ulothrix*, or others. Near Reykjavík a vertical section of such a surface showed uppermost, at the edge, *Pylaiella littoralis*, next *Rhodochorton Rothii f. globosa*, and lowest of all *Plumaria elegans*.

In a grotto in the Vestmannaeyjar, where the illumination was very feeble, *Enteromorpha intestinalis f. micrococca* occurred on the roof, *Ceramium acanthonotum* grew rather high up on the walls, and *Plumaria elegans*, together with *Delesseria alata*, formed a belt lower down the walls.

A vegetation corresponding to the shade-vegetation appears to occur in Greenland where *Hildenbrandia rosea*, *Ralfsia clavata* and *Verrucaria mucosa* form the undergrowth in the *Fucus*-belt and in other places (Rosenvinge, 63, pp. 198 and 203). *Rhodochorton Rothii* and *Sphacelaria britannica* also appear to grow in a similar manner in Greenland (Rosenvinge, 63, p. 205).

A comparison with the Færøes shows some difference. The vegetation in the grottoes in the Færøes (Börgesen, 12, p. 739), however, resembles in its main features the Iceland shade-vegetation, and, in addition, a similar vegetation is beyond doubt to be found in fissures and clefts of the rocks in the Færøes, but the mode of occurrence of the species is not the same. Thus, in the Færøes (Börgesen, 12, p. 711), the *Hildenbrandia*-association appears to have a much wider distribution upwards and to occur in fully illuminated localities. *Rhodochorton Rothii* seems to occur in a similar manner

in the Færøes (Börjesen l. c., p. 718) as it does in Iceland, with this difference, however, that the species extends higher upwards in the Færøes and, also, frequently grows in fresh-water in the latter place.<sup>1</sup> *Sphacelaria britannica* grows similarly in the Færøes (Börjesen, 13, p. 432).

According to Foslie (18) a similar shade-vegetation appears to occur in northern Norway.

This vegetation is a natural upward continuation of the semi-littoral *Polysiphonia urceolata*-association mentioned below.

### cc. The Vegetation of Tide-Pools.

Where there is a rocky coast, depressions of varying sizes occur everywhere in the littoral zone. These depressions may be divided into two groups: The tide-pools of the upper littoral zone, and the tide-pools of the lower littoral zone. The plant-growth in these tide-pools does not form a vegetation-unit, and is chiefly composed of species either scattered or of social growth which belong to the littoral or semi-littoral communities; they are, however, here treated separately in order to further characterize the illustration of the littoral zone given in the above description.

Tide-Pools of the Upper Littoral Zone. Of these the uppermost, which are almost on the level of *Fucus spiralis*, are of the greatest interest, as they often contain species, or forms of species, which do not occur elsewhere in the littoral zone. These species are *Cladophora sericea* f. and *Fucus inflatus* f. *linearis*.

The water in the uppermost pools is not replenished with the recurrence of each high-tide, and this is especially the case in calm weather during neap-tide; if, simultaneously, dry weather occurs, the water evaporates, and this the vegetation cannot endure for any length of time. In rainy weather, on the other hand, the pools are filled with fresh water, and should this happen during neap-tide the salinity would be insufficient for any of the species to exist. At spring-tide the water in the pools becomes mixed with a fresh supply of sea-water, and the vegetation then lives, for a time, under good conditions. Thus, there are times during which the conditions in the pools are not favourable to algal life.

*Cladophora sericea* grows very socially in many places and, in

<sup>1</sup> When I visited the Færøes in October, 1897, I was at first surprised to find *R. Rothii* growing in streams at and above the upper limit of flood-tide; such a situation for it in Iceland was unknown to me.



small pools, often forms a continuous fringe, the upper branches either reaching to or lying on the surface of the water. In such pools *Chaetomorpha tortuosa* sometimes occurs in fair abundance loose upon the surface of the water; its filaments are usually densely matted together.

*Fucus inflatus* f. *linearis* grows even more socially. At times it is almost the dominant species in the smaller pools, although, rather frequently, several other species are found intermingled with it. This form is a biological variety of *Fucus inflatus* which, in the pools, exists evidently under less favourable circumstances; this is one cause of its small size and feeble structure, although another is that it is not exposed, to any extent worthy of mention, to the beat of the waves. Rosenvinge has especially shown this to be the case as regards Greenland. Rosenvinge explains the frequent occurrence of this form in the pools by the fact that the eggs of *F. inflatus* are carried into the water-filled depressions by the movement of the water and accumulate there. This explanation is undoubtedly correct, and, as Rosenvinge points out, all intermediate stages between the feeble pool-form and the typical form can be demonstrated. To any one who has seen this endless variation in nature, it seems so certain that it is due to the influence of outside factors, that experimental proof is almost superfluous.

The uppermost pools are generally extremely poor in species; and, besides those already mentioned, only *Enteromorpha intestinalis* occurs in any great abundance. Where the coast is exposed, the uppermost pools may, however, have a resemblance to the lower ones of the upper littoral zone — a natural consequence of the exposure. On more exposed parts of the coast a fringe of small *Monostroma Grevillei* is often found, almost on the surface of the water itself. At one place in E. Iceland I took the temperature of such a submerged plant-covering, and the thermometer showed 20° C. (June 13). The vegetation was also somewhat injured, and evidently did not prosper under these conditions.

High up on a rocky coast to the south of Vattarnes in E. Iceland, I came across a pool-vegetation. I did not measure the altitude of the spot, but I do not think that I was greatly mistaken in estimating it at 70—100 feet above sea-level. As regards the place, I noted in my diary — “High rocky coast, land-plants grew round the alga-pools. The water in the pools must be replenished with rain and heavy surf, which sometimes fail for long periods during



the summer. Many pools filled with decaying and dying algæ." The occurrence of algæ so high up can be imagined only on a very exposed coast facing the open sea, and even there it would be exceptional.

The dominant species of the vegetation in these high-lying pools consisted of *Fucus inflatus* f. *linearis*. Intermixed occurred *Chaetomorpha Melagonium* — which I never before had seen so high above sea-level — *Acrosiphonia* sp., *Dictyosiphon foeniculaceus*, *Pylaiella littoralis* and *Enteromorpha intestinalis* f. *typica*. The undergrowth consisted of *Hildenbrandia rosea*.

In another somewhat elevated and exposed place in the vicinity of Vattarnes, a number of small pools were found just below the *Verrucaria maura*-belt. *Hildenbrandia* and *Verrucaria mucosa* grew on stones at the bottom of these pools; in addition, *Fucus inflatus* f. *linearis* occurred fairly abundantly, although dying in the pools, which were deficient in water.

The lower pools in the upper littoral zone have a much more luxuriant vegetation. Here various littoral and semi-littoral species can grow in fair abundance. The water in these pools is replenished at each high-water, so here, the plants exist under fairly favourable conditions. The following species may occur dominantly or abundantly: — *Fucus inflatus* f. *linearis*, *Halosaccion ramentaceum*, *Monostroma fuscum*, *Enteromorpha intestinalis*, *Monostroma Grevillei*, *Dictyosiphon foeniculaceus* and *Castagnea virescens*.

Many species are found growing scattered, of which the following are most frequently met with: —

<i>Polysiphonia urceolata</i> .	<i>Phyllitis fascia</i> .
<i>Porphyra miniata</i> .	<i>Pylaiella littoralis</i> .
<i>Rhodomela lycopodioides</i> .	<i>Scytosiphon Lomentaria</i> .
<i>Rhodomenia palmata</i> .	<i>Chaetomorpha Melagonium</i> .
<i>Chorda Filum</i> .	<i>C. tortuosa</i> .
<i>Chordaria flagelliformis</i> .	<i>Cladophora gracilis</i> .
<i>Coilodesme bulligera</i> . <sup>1</sup>	<i>Monostroma undulatum</i> .
<i>Ectocarpus confervoides</i> .	<i>Ulothrix flacca</i> .
<i>Elachista fucicola</i> .	<i>Urospora Wormskioldii</i> .

The under-vegetation often consists of *Ralfsia deusta*, *Lithothamnion circumscriptum* and *Hildenbrandia rosea*.

Taken on the whole, the majority of the littoral species undoubtedly may be met with in the pools, and it should be especially

<sup>1</sup> It may be observed, as regards *Coilodesme*, that it is the more inflated the lower the water is in the pools.

noted that, when the semi-littoral species occur in the upper littoral zone, they are usually confined to the pools, a fact which proves that they do not essentially belong to the upper littoral zone.

### b. The Semi-littoral Zone.

The upper boundary of this vegetation is just at the lower boundary of the *Fucus*-belt. The vegetation covers the lower littoral zone, and extends, usually in the form of stragglers, below the limit of low-tide, down between the uppermost extensions of the vegetation of the *Laminaria*-belt, which in many places reach right up to the limit of low-tide. The semi-littoral communities consequently grow side by side with the *Laminaria*-associations below the limit of low-tide, to a depth of about 10 metres; they also occur as epiphytic vegetation on the *Laminariæ* at the depth mentioned.

Thus, the semi-littoral zone is that between the lower edge of the *Fucus*-belt and the *Laminaria*-belt. The breadth of the zone depends on the slope of the coast. If the coast is steep the zone is narrow, but if the coast slopes gently, it is broad. In this zone no single dominant community of extremely social and large species occurs, like, for example, the *Fucaceæ*-community in the littoral zone, and the *Laminariaceæ*-community in the sublittoral zone. The zone appears to lie too low for *Fucaceæ* and too high for *Laminariaceæ*.

Green and brown algæ occur in abundance in the semi-littoral zone, but the *Rhodophyceæ* are most richly represented. The semi-littoral associations occur both laid bare during low-tide and also continuously submerged to the depth mentioned.

It is easy to follow the upper boundary of the zone, even in places where the *Fucaceæ* are absent. The lower boundary can also be ascertained with comparative ease, if the large *Laminariæ* only are followed, and if the observer is not led astray by the small *Laminariæ*, which may occur in the depressions and pools of the lower littoral zone.

The semi-littoral zone comprises several associations which play a rather considerable part in the vegetation.

By authors who describe the algal vegetation on coasts where there is a change of tide these associations are generally considered to belong partly to the littoral and partly to the sublittoral vegetation. On coasts where there is no tide, the littoral vegetation has,

however, been subdivided. Reinke (58, p. 10) divides the littoral region near Kiel into an upper zone which is always laid bare at low-water, and a lower zone at a depth of 2—4 metres. So far as I can judge from the species enumerated, Reinke's upper zone corresponds approximately with the previously mentioned upper littoral zone, while the lower zone corresponds only in part with the semi-littoral zone here described. Gran (24, p. 11) records under the term "sublittoral vegetation" transitional formations which evidently, for the most part belong to the semi-littoral communities.

On the west coast of Sweden (Kylin, 45) the border-line between the littoral and sublittoral algal vegetations is, on the coast of Bohuslän, at a depth of 3—4 metres, and at Halland at a depth of about 5 metres. The upper part of the littoral zone seems to correspond to some extent with the above-mentioned upper littoral zone, while the lower part has something in common with the semi-littoral zone.

Where there is no tide, the boundary between an upper and a lower littoral zone is not, I think, so sharply defined.

#### 8. The *Monostroma*-association.

This vegetation is composed of relatively large, membranaceous, green algæ. *Monostroma fuscum* and *M. Grevillei* form associations in a rather considerable number of places in protected localities in the fjords, below the limit of low-tide, and to a depth of at least 4—6 metres. There, the association is most sharply defined, although it is fairly frequently found intermingled with other semi-littoral associations. In the lower littoral zone also, an abundant *Monostroma*-vegetation frequently occurs, both on a rocky substratum, and also very often as epiphytic vegetation in other associations, as, for example, the *Halosaccion*-association, the *Corallina*-association, the *Polysiphonia urceolata*-association and others. In water-filled depressions in both the upper and lower littoral zone the *Monostroma* species often occur abundantly.

*Monostroma Grevillei* var. *arctica* seems to belong more immediately to the littoral zone. In many places it is found entirely laid bare, sometimes on a clayey substratum, when it often attaches itself to small individuals of *Mytilus edulis*, and sometimes where the substratum of the littoral zone is pebbly. During April and May this vegetation is rather characteristic, because then, the species occurs for the greater part in the inflated stage. The bladders vary

greatly in size and form and may be at times considerably elongated, bearing then a striking resemblance to an *Enteromorpha*. Under calm conditions the inflated stage continues until the spores at the apex of the frond are ripe.

In several places in the fjords *Monostroma Grevillei* var. *typica* forms a luxuriant, characterizing vegetation at a depth of about 3—5 metres.

*Monostroma fuscum* very frequently forms associations of considerable extent in the fjords at a depth of about 4 metres. The specimens of this species which occur there are generally very large (*f. grandis*). These large specimens are rather frequently found at low-water mark, detached or floating at the water's edge, and then it may generally be taken for granted that a *Monostrometum* exists further out at a depth of about 4 metres.<sup>1</sup> Both in the fjords of E. Iceland and in Eyjafljörður in N. Iceland this *Monostrometum* occurred in the same characteristic manner, viz. alternating with a *Chordarietum*, a *Dictyosiphonetum* (*D. foeniculaceus*), a *Halosaccione-tum*, and a *Rhodymenietum*. Generally the order was that *Rhodymenia* grew deepest (as deep as 12 metres), and *M. fuscum* most frequently uppermost (at about 4 metres). *Alaria* and *Laminaria saccharina*, in addition, may be found growing scattered in such places, which makes the character of the vegetation still more heterogeneous.

*Monostroma undulatum* does not occur so abundantly as do the other *Monostroma* species. It is found growing rather luxuriantly, however, in pools in the lower littoral zone, and on the stems of *Laminaria* in comparatively low water.

*Ulva Lactuca*, also, is most nearly related to this association.

This association is very common in the Færøes (cf. Börgesen, 12, pp. 731 and 764), and occurs also in Greenland (Rosenvinge, 63).

### 9. The Chorda-association.

This association is composed of rather large, brown algæ. The fronds are either non-branching, thick filaments (*Chorda*, *Scytosiphon*), or else branched, as in almost all the others; one, *Coilodesme*, however, is almost leaf-like.

This association has an insignificant distribution, and is found usually in patches, where the substratum is clayey or somewhat muddy. It occurs both in the lower littoral zone above low-water mark, and to a depth of at least 4—6 metres. The members of the

<sup>1</sup> Strömfelt (70, p. 11) mentions this *Monostrometum* at Eskifjörður.



association are as follows: — *Chorda Filum*, *C. tomentosa*, *Chordaria flagelliformis* and *Dictyosiphon foeniculaceus*. *Scytosiphon Lomentaria*, *Castagnea virescens* and *Coilodesme bulligera* are also most nearly related to this association. Some of the species occur in such abundance that they may be said to form an association: this applies more particularly to *Chorda Filum*. A pronounced *Chorda Filum*-association occurs in many places at a depth of almost 3—4 metres (measured during low-water of spring-tide). The individuals are extremely long, about 6 metres and, to a great extent, float on the surface at low-tide. The substratum is, as a rule, clayish with pebbles here and there. This association is often almost pure, but scattered individuals of *Laminaria saccharina* are not rare, although they play no essential rôle in the vegetation. *Chorda Filum* also grows above low-water mark in the lower littoral zone, but there it does not really form associations, although it may grow luxuriantly in many places.

*Chorda tomentosa* is also social and grows more luxuriantly below low-water mark than above it. It often occurs in abundance as a component of the sublittoral vegetation.

*Chordaria* and *Dictyosiphon foeniculaceus* are species which grow socially, and rather frequently a *Chordarietum* or a *Dictyosiphonetum* is found, usually with a limited distribution both below low-water mark and above it, especially in water-filled depressions in the littoral zone. The remaining species which have been mentioned are also of rather social growth in many places, both below and above low-water mark, especially in pools. *Coilodesme*, for example, was rather frequent in tide-pools in E. Iceland, and sometimes at a very high level, but then the individuals were frequently inflated; in SW. Iceland the species grew at and below low-water mark in company with *Chorda Filum* and *Saccorrhiza*.

With the exception of the above-mentioned *Chorda Filum*-association, this vegetation occurs usually in patches, distributed between other associations. Thus it is closely connected with the *Enteromorpha clathrata*-association at the boundary between the upper and lower littoral zones, and with the *Rhodymenia*-association and the *Monostroma fuscum*-association at a depth of about 4 metres, as has been previously mentioned.

In the Færøes a similar vegetation occurs as a part of the *Stictyosiphon*-association (Börgesen, 12, pp. 762—763).



10. The Community of *Rhodymenia*.

The species are *Rhodymenia palmata* and *Halosaccion ramen-taceum*, both of which occur along the coasts in great abundance as pure associations. These two associations most frequently accompany each other, and seem to demand somewhat similar conditions of life. *Halosaccion*, however, extends the higher up in the littoral zone, but is then almost always submerged in water-filled depressions in that zone, while *Rhodymenia* extends the further down below the limit of low-tide. In *Rhodymenia* the form of the thallus is leaf-like and branching; in *Halosaccion* it is round and excessively or slightly branching.

The *Rhodymenia*-association. On regarding a steep rocky coast, where the succession of the associations is always most easily observed, it is seen that a luxuriant *Rhodymenia*-vegetation commences even at the lower boundary of the *Fucus*-belt. In many places the species occurs so socially that it predominates as a characterizing plant over relatively large stretches, both in the lower littoral zone and far below the limit of low-tide, to a depth of about 12 metres. On a gently sloping rocky coast, the upper boundary of the association is not so sharply defined, but if proper allowance is made for the depressions and elevations in such a littoral zone the boundary is fairly easily ascertained although it may then lie in very many curves. On a gently sloping pebbly coast, the same regular boundary is found as on a steep rocky coast and at about the same height, although the *Fucaceæ*-community is not present there.

Various algæ may occur on stones under the fronds of the *Rhodymenia*, as, for instance, *Hildenbrandia rosea*, *Ralfsia clavata*, *Sphacelaria radicans* and others; also a number of epiphytes, especially *Myrionemaceæ* and *Ectocarpaceæ*, often grow on old individuals of *Rhodymenia palmata*.

*Rhodymenia* occurs also epiphytically on the stems of *Laminaria* in the upper part of the *Laminaria*-belt.

The *Rhodymenia*-vegetation does not seem to be so luxuriant in Greenland (Rosenvinge, 63) as in Iceland. Possibly this is true also of the north of Norway (Foslie, 18). In the Færøes the *Rhodymenia*-vegetation is luxuriant, but seems to differ somewhat from that of Iceland, as it consists of a form with lower and more dense growth and narrower branches; this form also extends further up (Börgesen, 12, p. 727).

The Halosaccion-association also commences below the lower boundary of the *Fucus*-belt, and extends from there to a depth of about 5 metres below low-water mark. The species grows very socially, entirely covering the rocky substratum upon which it grows; it is very variable, and, while *f. densa* seems to extend rather high up, in pools in the littoral zone, it is *f. robusta* which, as a rule, reaches to the greatest depth. *F. subsimplex* is very common just below the *Fucus*-belt, where it grows so densely that it covers the substratum completely. It is very often interwoven with byssal-threads of *Mytilus edulis*. In this form, as in the laid-bare *f. robusta*, inflated shoots occur fairly frequently. As is the case with *Rhodymenia palmata*, this species is very frequently decoloured in the lower littoral zone; yet in both species the lower part of the frond is, as a rule, reddish in colour.

Of the epiphytes, *Elachista fucicola* is especially frequent, and various other species may also occur closely applied to *Halosaccion*, such as *Porphyra miniata*, *Monostroma fuscum*, *M. Grevillei* and others. At times the *Monostroma* species may be so abundant that they may be said to play a distinct rôle as epiphytic vegetation. Among the *Halosaccion* individuals, *Dumontia filiformis*, *Chaetomorpha Melagonium* and others often occur growing scattered at the very limit of low-tide.

A similar Halosaccion-vegetation occurs in northern Norway (Foslie, 18), and probably on the arctic coasts as well (Kjellman, 36; Rosenvinge, 63). In the Færøes the association is poorly represented (Börgesen, 12, 13).

#### 11. The *Polysiphonia urceolata*-association.

At and about low-water mark in the lower littoral zone, an association is found consisting principally of excessively branching, red algæ which I will name after the species *Polysiphonia urceolata*, which is dominant in the association. This vegetation frequently occurs on a flat or convex substratum of rock (lava-substratum) and often forms, especially in SW. Iceland, for example at Grotta near Reykjavík, a broad belt around *Corallina*-pools, near low-water mark.

The species which occur in greatest abundance in this association are *Polysiphonia urceolata*, *Cystoclonium purpurascens* and *Rhodomela lycopodioides*.

The *Polysiphonia urceolata*-association is very luxuriant

in many places at about low-water mark, and often covers rather large stretches of rock with a dense but, at times, low vegetation. As previously mentioned, it grows luxuriantly on flat rocks, without any protection whatever during the period of exposure, which is certainly short, and indeed exceedingly short during a heavy sea. Here, as in the upper littoral zone, the association occurs also on the face of the rocks, and the species seems as a rule to be larger than when on flat rocks. The association appears to have an extended vertical distribution since, as previously mentioned, it occurs as shade-vegetation or undergrowth in the upper littoral zone; furthermore it must be assumed that it has a larger sublittoral distribution than is shown by the dredgings, as it has been found outside the 10-metre contour (see below). From what I have seen, the stretch of shore just above and somewhat below low-water mark is essentially the home of this association. It usually grows on a rocky substratum and on *Laminaria* stems at no great depth.

*Cystoclonium purpurascens* grows socially in many places both on a rocky substratum and on *Gigartina*. Sometimes it occurs in such abundance as an epiphytic vegetation in the *Gigartina-Corallina*-belt, that it is the alga which characterizes the vegetation, and not until the plants are moved aside is it seen that they are attached to a living substratum. On *Cystoclonium* various epiphytes occur, for example, *Chantransia*, *Monostroma Grevillei* and others.

*Rhodomela lycopodioides* very frequently grows scattered, and then plays only an insignificant rôle in the vegetation; but *Rhodomela* of limited extent also occur, often in contact with the *Polysiphonia urceolata*-associations.

*Ceramium rubrum*, *C. acanthonotum* and *Callithamnion Arbuscula* really belong to this association. In many places these species grow fairly socially and *Ceramieta* of *C. rubrum* and *C. acanthonotum* and *Callithamnioneta* of limited extent occur both on rocky substrata and on one of *Gigartina*; however, I think that these species occur too sparsely to be termed association-formers.

*Sphacelaria radicans* also belongs to this association. Often, even at low-water mark, it covers flat stones with a dense vegetation, but though these small *Sphacelarieta* are considerably distributed, yet they cannot be called associations.

In the Færøes a similar *Polysiphonia urceolata*-vegetation occurs (Börgeren, 12, p. 731).

## 12. The Community of *Corallina*.

The members of this community are *Corallina officinalis*, *Gigartina mamilliosa*, *Chondrus crispus* and *Ahnfeltia plicata*. These species occur as a rule in luxuriant and more or less sharply defined associations, which very frequently occur together, and may therefore be regarded as nearly related to each other.

The fronds are branched, and their consistency is on the whole firm because, as is known, *Corallina* is encrusted with calcium carbonate, *Ahnfeltia* is horny and *Gigartina* and *Chondrus* are cartilaginous.

*Gigartina* and *Corallina* generally occur in a belt at the limit of extreme low-water; in my diary I have always called this belt the *Gigartina-Corallina*-belt. *Gigartina*, however, extends higher up; on exposed coasts right up to the *Fucus*-belt, and even into that as under-vegetation; but, where *Gigartina* and *Corallina* meet, there is most frequently a mixed belt. These associations belong to S. and SW. Iceland.

The *Corallina*-association occurs most luxuriantly about low-water mark. The species grows extremely socially, and entirely covers depressions in the littoral zone which are more or less filled with water. The association occurs on somewhat exposed and also on very exposed coasts, but almost always in depressions surrounded by rocks upon which the waves break; yet I have seen it, where the exposure is but slight, covering the face of rocks below low-water mark. Only rarely have I obtained *Corallina* by dredging in greater depths, as, for example, on the north coast, at a depth of about 14 metres, where it seems to be present in abundance. It may be assumed with certainty, however, that this association has a much wider distribution below the limit of low-tide than is shown by the dredgings, and with exceptional low-tides it can be seen that in many places the *Corallina*-vegetation covers the rocks as far as the eye can reach.

On a very exposed coast I have met with *Corallina* growing socially in water-filled depressions at a considerable higher level, sometimes on a level with the upper part of the *Fucus*-belt. Here, however, with the exception of the lowest part of the frond, it is quite white in colour, and has evidently strayed outside its real domain. The spores have been carried to this height above the true *Corallina*-belt by the beat of the waves, and have been retained in the depressions. It can also thrive fairly well at this height during



the autumn and winter, both because the light is feeble, and because the increased high seas following stormy weather to some extent compensate for the difference in height. But it is in the spring and summer that it is most evident that *Corallina* has really extended too high up. According to Børgesen's description (12) it appears to extend still higher up in the Færöes.

In the *Corallina*-association an abundant epiphytic vegetation may occur, both of small algæ like *Chantransia* and of larger algæ such as *Monostroma Grevillei*, *Spongomorpha vernalis*, *Acrosiphonia albens* and also the *Leathesia*-associations. Furthermore, *Ceramium rubrum*, *Cystoclonium*, *Delesseria sinuosa* and *D. sanguinea* occur, and other red algæ, often in great quantities. When to this is added the fact that *Gigartina* is often abundantly intermingled with those already mentioned, it is easily seen that this mixed vegetation assumes quite a different character, according as to whether the brown-red *Gigartina* and *Ceramium* or the light-green *Monostroma* and *Spongomorpha* predominate. This characteristic appearance differs entirely from the usually monotonous appearance of the *Corallina*-belt. This epiphytic vegetation must be considered to form associations which do not really belong to the *Corallina*-vegetation in any other respect than that of having it for a substratum.

The *Gigartina*-association is widely distributed on very exposed coasts; it often is of very great breadth and, as already frequently mentioned, extends in under the *Fucaceæ* as undergrowth. Where the exposure is less, it does not reach so high; but yet, in the lower littoral zone there is, as a rule, a distinct *Gigartina*-belt, which most frequently occurs above the limit of low-tide. The *Gigartina*-vegetation extends also below the limit of low-tide, but it seems to belong most closely to the lower littoral zone. The belt is quite characteristic, and can often be seen from a distance, as the colour is in strong contrast to that of the *Fucaceæ*-community. The species is of very social growth and is usually dominant where it occurs; not rarely, however, a few species occur intermingled with it, especially in the Vestmannaeyjar and at Öndverðarnes, two very exposed localities. In the *Gigartina*-belt *Corallina* may occur lowest, *Callithamnion Arbuscula* is sometimes plentifully intermixed with the *Corallina* and occurs also in abundance as an epiphyte, and *Ceramium acanthonotum* occurs rather frequently and often abundantly. In the Vestmannaeyjar *Callithamnion scopulorum* occurs rather frequently as undergrowth. In addition, *Ceramium rubrum*,



*Delesseria alata*, *Acrosiphonia*, *Polysiphonia urceolata*, *Plumaria elegans* and *Rhodymenia palmata* occur. *Porphyra umbilicalis* occurs as an epiphyte in the Vestmannaeyjar, and also *Cystoclonium*, *Polysiphonia urceolata* and others.

The *Gigartina*-belt is very luxuriant in the Vestmannaeyjar and at Öndverðarnes; it may be said to be, on the whole, luxuriant in S. and SW. Iceland. As regards the relations between *Gigartina* and *Corallina*, the following observation from the Vestmannaeyjar may be recorded. At Brimsurð, on the south-east side of the inhabited island, where the littoral zone consisted of large, although not particularly high boulders, these were entirely covered above by a dense *Gigartina*-vegetation, while *Corallina* formed just as dense a belt around them below.

*Chondrus crispus* also grows socially in S. and SW. Iceland. It is true that *Chondreta* of lesser extent occur usually at or near low-water mark, but nowhere does the species occur nearly as luxuriantly as does *Gigartina*. The *Chondrus*-vegetation is most luxuriant in the Vestmannaeyjar and at Eyrarbakki. Between the skerries off the latter place, the broad-fronded form grew in abundance, both above and a little below the limit of low-tide. In both the places mentioned, which belong to S. Iceland, it grows in such abundance that the vegetation might almost be termed an association; in SW. Iceland on the other hand, it seems to occur more sparsely, and the small *Chondreta* may then be considered to belong to the *Gigartina*-association.

*Ahnfeltietum*. *Ahnfeltia plicata* grows socially in S. and SW. Iceland and usually forms a narrow belt at and below the limit of low-tide. The individuals are very frequently matted together by the byssal threads of various small molluscs, and worms and quantities of snails are found between the plants. In reality this vegetation is more nearly related to the *Corallina*-association than to the *Gigartina*-association. This species grows also scattered among *Corallina* and *Gigartina*.

The intermingled species are only few in number, for example, *Ralfsia deusta* which may occur abundantly in small depressions, and *Leathesia difformis* which sometimes occurs in abundance as an epiphyte. *Ahnfeltia* is most frequently decoloured above low-water mark.

*Chætomorpha Melagonium* occurs rather frequently, grow-

ing scattered in the *Corallina-Gigartina*-belt, without playing any further part in the vegetation.

The *Leathesia*-association is here mentioned in connection with the *Corallina-Gigartina*-belt. The brown, spherical, cartilaginous *Leathesia difformis* is found in abundance in this belt only, and I prefer to mention it here rather than to place it in the *Chorda*-association. The species occurs only as an epiphyte, not only on *Ahnfeltia* but also on *Corallina*, *Gigartina* and *Chondrus*, and is often wonderfully numerous. The size varies greatly, often the globules may be rather large and, by their yellowish colour greatly alter the appearance of the vegetation. It often almost entirely covers rather extensive *Corallineta*. The species is a summer-form, which does not occur in any quantity worthy of mention until the month of June, flourishes during July and August, and disappears in September, at any rate in SW. Iceland.

Small specimens of *Leathesia* occur also on *Rhodymenia palmata*.

### 13. The Crustaceous alga-association.

At low-water mark and in the lower littoral zone, there occurs a crustaceous algal vegetation which may be considered a direct continuation of the sublittoral crustaceous algal vegetation (see below, p. 148). Here, the species are, for the most part, the same, e. g. *Lithoderma fatiscens* and *Lithothamnion compactum*. Both these species often have a somewhat considerable distribution in the lower littoral zone. The *Hildenbrandia*-association mentioned as existing in the upper littoral zone also occurs here. *Lithothamnion leve* and *Phymatolithon polymorphum* also occur in the lower littoral zone. In addition, we have *Ralfsia deusta* which, in many places, forms patches upon the bottom of pools in the lower littoral zone, and plays rather an important rôle in the vegetation.

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Tide-Pools of the Lower Littoral Zone are most frequently depressions which are either directly connected with the part which is constantly submerged or separated from it by a ridge; which may happen to be the case is unimportant as the period of exposure in this part of the littoral zone is extremely short, as is also seen from the fact that the vegetation in these depressions consists of sublittoral associations, or more correctly, of stragglers from them. Thus, *Laminaria* and *Alaria* species frequently occur in

these depressions which fact will be mentioned again later on. Some of the depressions are occupied by semi-littoral associations, thus, *Corallineta*, *Gigartineta*, *Chondrela*, *Monostrumeta*, *Ceramietta*, etc. frequently occur, and, in addition, several of the species which belong to these associations are found growing in a scattered manner.

As mentioned above (p. 125), the vegetation in the pools is highly heterogeneous, and, in the large pools it can frequently be seen that the associations or their representatives arrange themselves in belts, here on a small scale in the same manner as they do on a larger scale outside the pools.

### c. The Sublittoral Zone.

The sublittoral vegetation covers the sea-bed from the limit of low-tide down to a depth of 40—60 metres, and perhaps to an even greater depth. Under normal circumstances it is not exposed during low-tide; yet it may happen that the uppermost *Laminarie*, especially when small, become exposed during extreme low-water, but this must be considered exceptional. What especially characterizes this zone is the circumstance that the associations are always submerged. The associations are certainly few in number, but most of them have a remarkably wide horizontal distribution, and the vegetation, taken as a whole, is homogeneous. With the exception of illumination the conditions of life must be supposed to be stable; in any case, compared with the conditions of life in the littoral zone, they are unstable to a very slight degree. In the littoral zone the change of season is noticeable, but in the deep, under normal circumstances, these changes are very slight. The character of the vegetation is therefore nearly the same all the year round.

The *Laminariaceæ* vegetation, as previously mentioned, is dominant in this zone and stretches in a broad belt along the coasts. Beyond the *Laminaria*-belt another narrower belt occurs composed almost exclusively of *Rhodophyceæ*.

### 14. The Community of Laminariaceæ.

This community occurs especially on a rocky substratum, and extends over large areas of the sea-bed from about the limit of low-tide to a depth of about 30 metres. It forms a belt round the coasts, and varies in breadth according to the conditions of depth and the nature of the substratum. This belt is for the most part

continuous, although only as far as the substratum is favourable for its development. By reason of the nature of the substratum, both the upper and the lower boundaries often have an irregular course, and stragglers from the main body of the vegetation often occur. Those *Laminariaceæ* which occur in the low-lying tide-pools must be regarded as stragglers from the *Laminariaceæ*-community which exists below. In the same way there are stragglers which extend outwards into deep water, as some members of the community have been found at a depth of 40 metres. The community occurs both on exposed coasts and on those which are partly exposed, as well as on sheltered coasts. It is composed of perennial species with, as a rule, strongly developed organs of attachment, a stem-like stipe and, as a continuation of this, a lamina or leaf-like portion which is originally undivided, but in some of the species, is later divided by longitudinal slits into many lobes. The species are the largest of all the algal species in the northern seas: they grow both in pure associations and highly intermingled with one another. The community may be said to resemble a "forest" on the sea-bed; sometimes the "forest" is pure, sometimes mixed, and it has its undergrowth, its "stem" epiphytes and its "leaf" epiphytes.

The species which occur are *Saccorrhiza dermatodea*, *Laminaria*-species and *Alaria*-species. Like the *Fucaceæ*-community in the littoral zone, the *Laminariaceæ*-community is composed of a few species of very social growth, and, just as the *Fucaceæ*-community forms the greater part of the bulk of the vegetation in the littoral zone, so does the *Laminariaceæ*-community below the limit of low-tide. If the range of the associations differs in depth this will be mentioned when they are described.

The Associations of the *Laminariaceæ* Community occur in many places in fairly regular succession from the coast out towards the deep sea. Thus, often quite close to the coast, *Laminaria saccharina* or *Alaria esculenta* is found occurring in very great abundance in pure or mixed associations; beyond is found a belt of *Laminaria digitata*; and deepest of all *Laminaria hyperborea*. But the order is not always so regular, and at lesser depths it is frequently seen that the species occur socially on small areas of the substratum, sometimes one species being dominant and sometimes another. The species may also occur scattered amongst one another, especially at lower depths. There is a difference in the



character of the community in sheltered and in exposed places, which is evident from the description of the association given below. In sheltered places the calm-water character predominates; to this belong the *Saccorrhiza dermatodea*-association, the *Alaria Pylaii*-association, the *Laminaria færoënsis*-association and the calm-water associations of *L. saccharina* and *L. digitata*. Of the very much exposed associations, the only essential one to be recorded is the *Stenophylla*-association (see under *L. digitata*). In addition, a difference is evident according to the depth, and the associations then occur either with a shallow-water character or with a deep-water character (see below).

In its main features, this community occurs in a similar manner on the coasts of adjacent countries. The communities of S. and SW. Iceland greatly resemble those of the Færøes, as has been frequently mentioned, and also those of western Norway (Boye, 10; Hansteen, 25) and of Finmark (Foslie, 18).

The *Saccorrhiza dermatodea*-association. I have most frequently found this species just below the limit of low-tide, where it is of medium size, and grows scattered. In water-filled depressions in the lowest part of the littoral zone which, although they lie above the limit of low-tide, belong from a biological point of view to the lower-lying area, the species is often very social and forms pure associations. I have found it growing very socially at a greater depth (22—28 metres) within Reyðarfjörður in E. Iceland off Hólmanes or thereabouts; the specimens which occurred there were of large size. When the various *Ectocarpaceæ* which may occur on old individuals are excepted, the plants are usually free from epiphytes. The association develops best in somewhat sheltered places.

The *Alaria Pylaii*-association. *Alaria Pylaii*, as mentioned below, often grows interspersed amongst *Alaria esculenta* f. *pinnata*, *Laminaria saccharina* and others, in somewhat exposed places; but its real habitat is in the interior of the fjords, where the water is calm. Here occur the typical, large, broad-fronded individuals: they are often social in growth and then form pure or almost pure associations; but they are most frequently distributed in patches, and then alternate with *Saccorrhizeta* or social growths of *Laminaria nigripes* v. *atrofulva*. In such places occur also the broad-fronded calm-water forms of *Laminaria saccharina* and *L. digitata*. *Alaria*



*Pylaii* occurs thus as a calm-water form corresponding with the deep-water form of *Alaria esculenta* and with the form found on exposed coasts. I have found the *Alaria Pylaii*-association well developed in E. Iceland at a depth of 20 metres. The species also extends higher up and may, like all the other *Laminariaceæ*, occur at about the limit of low-tide or in the water-filled depressions in the lower littoral zone, but is then, like those *Laminariaceæ*, of small growth.

The *Laminaria færøensis*-association. The species in question grows socially at a depth of 20—30 metres in Fossárvík at the head of Berufjörður in E. Iceland. In its external appearance this association exactly resembles the deep-water association of *Laminaria saccharina*. The structure of the stipe differs however, because *L. færøensis* has a hollow stipe like *L. longicruris*; as Rosenvinge (63, p. 211) and Börgesen (12, p. 766) point out, the air-filled hollow space probably serves to lift the large lamina from the sea-bottom.

In deeper water, *L. færøensis* occurs in the same manner in the Færøes as it does in E. Iceland (Börgesen, loc. cit., p. 766), but differs somewhat in shallow water. In Greenland and Iceland, as in the Færøes, the hollow-stemmed *Laminariæ* prefer protected localities.

The *Alaria esculenta*-association. This is distributed very commonly along all the coasts of Iceland. It prefers a rocky substratum, but may occur also on pebbles as *Laminaria saccharina* occurs, and frequently in company with it. As a rule, the association is best developed at a depth of 6—16 metres; but the species occurs, in addition, growing socially at a depth of 3—4 metres and again, sometimes as deep as 30 metres. The association is pure or only slightly mixed, and then usually with *L. saccharina*, *L. digitata* or *Al. Pylaii*; it often stretches for miles in the fjords. The species (*Alaria esculenta*) varies in a manner somewhat similar to the variations of *Laminaria saccharina* and *L. digitata*. In very exposed places, there is found in shallow water a narrower-fronded form with narrow, leathery sporophylls. This form cannot be termed a surf-form like *L. digitata* f. *stenophylla* but it may, however, merit the title of an exposure-form. Another form, which is much larger, both as regards the length and breadth of its fronds, occurs in deeper water

(*f. pinnata*). This alga is one of the largest found on the coasts of Iceland, and may at times attain a length of 6—8 metres. The form of the frond resembles to some extent the shallow-water form of *Laminaria saccharina*, the thick mid-rib of *Alaria* corresponding with the thickened median area of *Laminaria*. The fronds of both species are thus well adapted to withstand the motion of the waves; in fact both species are rather frequently found intermingled in a broad belt along the coasts. On many of the sunken skerries which are such a danger in navigation, *Alaria esculenta* is the principal species, indeed frequently growing alone. In Hvammsfjörður in SW. Iceland, in places where a strong current exists (Röstin) there was found a dense vegetation of broad-fronded *Alaria esculenta f. pinnata* with very long laminæ.

It is general knowledge that the lamina is torn in pieces by the waves, and cases are frequent also in which the thin part of the lamina is divided into many pieces by transverse slits, often nothing remaining save the mid-rib itself, especially in the upper part of the lamina. A luxuriant *Alarietum* was found below the limit of low-tide at the extreme point between Seyðisfjörður and Loðmundarfjörður; it consisted mainly of *Alaria esculenta f. pinnata* with *Alaria Pylaii* and *Lam. saccharina* intermingled. It was at once noticeable that the uppermost *Alariæ* were entirely frondless; the stipes were completely overgrown with *Ectocarpaceæ*. It must be admitted that the situation was exposed, and therefore it may well be that the laminæ were destroyed by the beat of the waves; but there is just as much reason to believe that this was occasioned by the drift-ice, which had made its appearance on the coasts some time before my arrival. In this locality the *Fucus*-belt had also been scraped off the rocks in several places which, in my opinion, was caused by the drift-ice.

The *Laminaria saccharina*-association. This association is very luxuriant, and occurs almost pure over stretches extending for miles along the coasts. It does not always grow on a firm, rocky substratum: rather frequently it occurs on a pebbly substratum, in which case the plants are attached either to a single pebble or to several, as if lying at anchor. With dredgings, therefore, it rather frequently happens also that the plants with their "anchors" are dragged up from the sea-bottom. This association is met with from a depth of about 2 metres, or from

about the limit of low-tide, down to a depth of about 30 metres. Small individuals may be found in the lowermost water-filled depressions of the littoral zone. Compared with the other commonly distributed *Laminaria*-species, *L. digitata* and *L. hyperborea*, then *L. saccharina* generally keeps nearest to the coast, especially the more leathery, shallow-water form. In shallow depths the succession can be perceived distinctly, but with regard to greater depths conclusions must be drawn from what is brought up by the dredge. The succession usually is, that while *L. saccharina* keeps nearest to the land *L. hyperborea* extends deepest.

As is well known the species varies very much, according to the depth and the degree of exposure. A form with leathery, thick fronds with a rough surface occurs near land on somewhat exposed coasts in those depths where the effect of the beat of the waves is distinctly observable. At greater depths another form occurs, the deep-water form, with long, broad and comparatively thin fronds; and in protected localities inside the fjords of E. and W. Iceland a third form occurs at a depth of 4—20 metres. This form (*f. latifolia*) is long-stemmed, with comparatively very broad lamina and an entirely smooth surface. As each of these forms grows very socially the character of the association varies in accordance with the depth and the exposure.

The *Laminaria digitata*-association. This association is very common everywhere along the coasts where there is a rocky substratum, from a depth of about 4 to about 25 metres. On rocky coasts, however, small specimens occur just at the limit of low-tide, and there represent a kind of boundary. Small individuals may occur also in water-filled depressions in the lowest part of the littoral zone.

The tendency of *Laminaria digitata* is to vary in the same manner as *L. saccharina*, and thus the character of the association differs according to the depth and the degree of exposure, as the forms, individually, grow socially. The typical appearance of the association is determined by the deep-water form, or the typical form, which seems to grow most luxuriantly at a depth of about 10—20 metres. Here the species attains its greatest length and, as a rule, the stipe is so strong that it is able to raise the much-divided lamina from the bottom.

Just as the forms are connected with one another by inter-

mediate forms, so are the various associations connected. If the deep-water character of the association is taken as a starting point, we notice that it changes gradually with decreasing depths on exposed coasts, and that somewhere near the limit of low-tide it assumes an entirely different character, which is displayed in the leathery, long-stemmed form with a narrow and slightly-divided frond (*f. stenophylla*). On an exposed coast this variety might be termed the shallow-water type or perhaps, rather, the surf-type, in conformity with the surf-form of *Fucus inflatus*. The surf-character was very beautifully and typically developed in the Vestmannaeyjar; here *f. stenophylla* grew very socially, forming a continuous belt, the upper boundary of which occurred almost at the limit of low-tide. When during low-tide the waves receded it was very interesting to see how easily the leathery, narrow, slightly-divided laminæ moved with the waves, and everywhere, as far as the waves receded, the rocky substratum between the *Stenophylla*-individuals was quite reddish in colour from the encrusting *Phymatolithon polymorphum*. The *Laminaria* plants were very firmly attached to the rock — a fact evidently well known to the fishermen, as they fastened the boat to a *Laminaria* while we went ashore. The stipe is leathery and pliable, and the plants cling closely to the substratum when the waves recede.

I have found *f. stenophylla* in other places, although not in such abundance, and not quite so typical. Here the same rule applies as with regard to *Fucus inflatus* and *Laminaria saccharina*, that the tendency to vary seems to depend on the greater or lesser movement of the water; on coasts which are somewhat exposed, a *Laminaria digitata*-association is rather frequently found at about the limit of low-tide, with a character midway between the surf-character and the deep-water character.

If we again take the deep-water character of the association as a starting point, and move inwards towards the protected coasts, we see that the character changes again, but in another direction. The stipe becomes shorter and the frond much broader and slit into fewer and broader lobes. Within the fjords, in W. and E. Iceland especially, the character is entirely different from the deep-water character. Here occur forms with very broad fronds which are either undivided or divided into two, or a few, very broad lobes (*f. cucullata*). Generally the depth is about 4—20 metres, even deeper occasionally. I have found associations with this character



well developed in E. Iceland. At an insignificant depth, where I was able to see the sea-bottom, the individuals were not really closely placed, but lay on the bottom, some quite flat, and others slightly obliquely with the hollow surface turned upwards to the light. In this way the sea-bottom was almost entirely covered by the broad fronds.

This character might be termed the calm-water character, and an association-character exactly corresponding with it is found in *Laminaria saccharina* and *Fucus inflatus*.

*Laminaria digitata* f. *cucullata* occurs also scattered among *Laminaria nigripes* v. *atrolfulva* and *Alaria Pylaii*.

The *Laminaria hyperborea*-association. It is developed luxuriantly in S. and SW. Iceland, and occurs also in E. Iceland and N. Iceland, in those places which I have visited. I can pronounce no opinion upon its general distribution in N. Iceland, as dredgings have been undertaken there in a few places only; yet I think that it occurs everywhere there. In E. Iceland, on the other hand, where I have done a great deal of dredging, I have only found it at the mouth of Berufjörður. It is very luxuriant in the Vestmannaeyjar, forming a continuous belt round the inhabited island.

The association grows on a rocky substratum, from a depth of about 4 metres to about 30 (or 40) metres, and occurs both on exposed and on slightly exposed coasts; close to the limit of low-tide and in water-filled depressions in the lowermost part of the littoral zone small specimens may occur. In shallow water, with exceptional low-tides, the upper part of the stipe is frequently seen rising above the surface, raising the lower part of the frond obliquely above the water. Börgesen (12, p. 755, Fig. 160) has reported and illustrated this from the Færøes.

In Iceland *L. hyperborea* does not vary in the same manner as do *L. saccharina* and *L. digitata*, the fact being that it does not occur in protected places, and on exposed coasts does not extend so far up as the two species mentioned. Those specimens which occur close to the limit of low-tide, or in pools in the littoral zone, are quite as typical as the large, deep-water individuals. The association seems to thrive best at a depth of about 20 to 30 metres, but on somewhat exposed coasts it also thrives fairly well at lesser depths, and is then very frequently mixed with the other members of the community; while at greater depths it is generally pure. As



is generally known, the species has very strong haptera, often arranged in rows, which issue from the lower part of the stipe, so that the haptera appear one above the other in vertical succession. They then look like a vertical row of obliquely placed props, one above the other; such rows issue in all directions from the stipe. By this it must be understood that, as the plant grows, new haptera appear, usually in the regular succession mentioned, until such time as the plant attains its normal size. The development of the haptera must necessarily keep pace with the rest of the growth, because the larger the plant becomes so much the more is it moved by the waves, and so much the stronger must the props become if the plant is not to be torn up. The youngest props are the longest, and are situated at the extreme (upper) end of the row. That the growth of the organs of attachment is contemporaneous with the increase in size of the individual applies also, of course, to the other *Laminariaceæ*, but scarcely anywhere is it seen so distinctly as in this species.

In its main features *L. hyperborea* behaves in Iceland — at any rate in S. and SW. Iceland — in the same manner as it is recorded by Börgesen (12, p. 755) to behave in the Færøes.

The Under-vegetation. No doubt an abundant under-vegetation occurs everywhere, chiefly formed of crustaceous algæ as a lower layer, and of branching or membranaceous *Rhodophyceæ* and a few *Phaeophyceæ* in addition as an upper layer. Here, as in the *Fucus*-belt, it must be assumed that the under-vegetation is of no real value to the upper; while, on the other hand, the latter affords protection to the under-vegetation — in the *Fucus*-belt against desiccation and too strong light, and in the *Laminariaceæ*-community against strong movements of the water. The subdued light caused by the *Laminaria* fronds is, no doubt, also of importance in the upper portion of the *Laminaria*-belt, in so far, at any rate, that the species with a more downward range may endeavour to attain greater heights. In the lower portion of the *Laminaria*-belt the subdued light does not seem to affect the under-vegetation very much which seems to thrive there just as well as in open places where *Laminariaceæ* are absent; to have the waves moderated may be beneficial to the under-vegetation, especially in shallow water. During excessive ebb-tides opportunities may occur in many places of seeing how the *Laminaria* fronds moderate the motion of the waves, that is when this is not too violent, as, for example, when it approxi-

mates to surf. In deep water the *Laminaria* fronds will always moderate the motion.

In shallow water, especially where the bottom can be seen, it is easy to observe the under-vegetation, but in deep water one has to rely upon the specimens brought up by the dredge.

The under-vegetation is not divided according to the various associations of the upper vegetation, but seems to possess the same character wherever it is observed. In S. Iceland (the Vestmannaeyjar and Eyrarbakki) *Phymatolithon polymorphum* occurs in great abundance, covering the bottom entirely for large distances near the coast as an undergrowth. It is mainly composed of crustaceous, membranaceous, and more or less branching *Florideæ*.

A. Crustaceous Algæ. In several places in N. and E. Iceland I found a luxuriant under-vegetation formed of *Lithothamnion læve*, *L. circumscriptum* and *L. glaciale*. Among these species the first mentioned especially seemed to be widely distributed both on the bottom of an *Alaria* and a *Laminaria* association. In E. Iceland *Lithothamnion flavesceus* and *L. foecundum* in addition, like *Clathromorphum compactum*, were very frequent on a *Laminaria*-association-bottom. Together with these species occurred *Peyssonellia Rosenvingii*, *Cruoria arctica*, *Lithoderma* and others, as in the crustaceous algal vegetation (see p. 155).

B. Membranaceous and Branching filamentous species. The upper layer, with which are also associated intermingled species, varies considerably according to the depth. In addition to a number of the species which extend further downwards, various semi-littoral species may thus occur in the upper part of the *Laminaria*-belt. A number of the species which grow on the *Laminaria* stems may also occur on the bottom between the *Laminariæ*.

Here it is really a question of several associations; the lowest layer, as mentioned, is the crustaceous alga-association; the second layer is composed in its upper part of semi-littoral associations, which meet the associations which extend deeper and are mainly associations of *Rhodophyceæ*; and the uppermost layer is the *Laminaria*-association. The species are named where these associations are mentioned, and are therefore omitted here.

The Epiphyte-vegetation. Epiphytes very frequently occur on the stipes and laminæ of the *Laminariaceæ*, and it is a particularly common occurrence for old stems of *Laminaria hyperborea* to be entirely overgrown, for the epiphytic vegetation is much more

luxuriant on this species than on the remaining *Laminariaceæ*. It happens rather frequently, however, that a rich epiphytic vegetation occurs on *L. digitata*, *L. saccharina*, *Alaria esculenta* and *Saccorrhiza dermatodea*. The epiphytes generally occur most abundantly on the older individuals. The vegetation on the stems is usually composed of species which may be found growing among the *Laminariæ*, and then belong to the second layer of the under-vegetation, which can thus be raised upon the *Laminaria* stems; consequently, it is very natural that the composition of the species of the epiphytic vegetation should vary according to the depth. The following distinction is evident: that the semi-littoral species which grow epiphytically in shallow water vanish as the depth increases; while, on the other hand, some of the deep-water species may occur at a relatively lesser depth.

The following species have been found to occur on stems of *Laminariaceæ*, and may almost all be found on *Laminaria hyperborea*: —

Ahnfeltia plicata.	Rhododermis parasitica.
Antithamnion floccosum.	Rhodophyllis dichotoma.
A. Plumula v. boreale.	Rhodymenia palmata.
Ceramium rubrum.	Desmarestia aculeata.
Delesseria alata.	D. viridis.
D. sanguinea.	Ectocarpus confervoides.
D. sinuosa.	E. fasciculatus.
Dermatolithon macrocarpum.	E. Hinksia.
Euthora cristata.	E. penicilliformis.
Gigartina mamillosa.	E. siliculosus.
Lithophyllum Crouani.	E. tomentosoides.
Lithothamnion circumscriptum.	Isthmoplea sphærophora.
Lomentaria clavellosa.	Laminaria digitata.
L. rosea.	L. hyperborea.
Odonthalia dentata.	Leptonema fasciculatum.
Petrocelis Henedyi.	Litosiphon filiformis.
Peyssonellia Rosenvingii.	Sphacelaria olivacea.
Plocamium coccineum.	S. radicans.
Polysiphonia arctica.	Monostroma fuscum.
P. parasitica.	M. Grevillei.
P. urceolata.	M. undulatum.
Porphyra miniata.	Ulothrix flacca.
Ptilota pectinata.	Ulva Lactuca.
P. plumosa.	Ulvella fucicola.
Rhodochorton repens.	Urospora Wormskioldii.
R. Rothii.	51 species in all.

In addition, the fungus *Dothidella Laminariæ* must be mentioned; it is a very common endophyte in the stipe of various

*Laminariaceæ*. It occurs most commonly at depths of from 6—20 metres, but has also been found as deep as 30 metres.

Many of these species grow very socially and often cover the stipes completely, or nearly so. At Reykjavík, it is very usual in the spring to find *Laminaria hyperborea* in shallow water (4—10 metres) with the stipes entirely overgrown by *Rhodochorton Rothii*, *Antithamnion floccosum* and *Polysiphonia urceolata*, each on its own particular stipe, or else intermingled. *Petrocelis* and *Rhododermis* occur also in great abundance, almost covering entire stipes. In the Vestmannaeyjar and at Eyrarbakki it was also a fairly common occurrence to find stipes of *Laminaria hyperborea* completely overgrown by *Dermatolithon macrocarpum*. In the northern part of the country *Lithophyllum Crouani* also sometimes covers the stipe of *L. hyperborea* over its entire length. Many of the remaining species may also occur abundantly, but most frequently the vegetation upon the stipes is mixed, and crustaceous species grow side by side with branching and membranaceous species.

The epiphytic vegetation seems to be most luxuriant and richest in species at lesser depths, where the semi-littoral associations meet the associations which extend deeper down, and where, in addition to the *Rhodophyceæ* which always predominate, both brown and green species occur. At a greater depth the species are few, and are almost exclusively *Rhodophyceæ*. Generally, the rule seems to hold good that while the species with a more downward range occur on the haptera or on the lower part of the stipe, the more light-loving species occur on the upper part of the stipe; the green algæ, however, are by no means always uppermost. Thus in the upper portion of the *Laminaria*-belt *Euthora*, *Rhodophyllis*, *Odonthalia* and others frequently occur among the haptera, but in the lower portion of the belt they may be found on the stipe almost everywhere, especially *Euthora*. This agrees with Berthold's observation of the succession of epiphytes on *Cystosira* in the Mediterranean, and with Börgesen's observation of the order of the epiphytes on *Laminaria hyperborea* in the Færøes.

The vegetation on the stipe of *L. hyperborea* is extremely luxuriant in S. and SW. Iceland and is considerable both in NW. and N. Iceland, but is poor in E. Iceland.

Epiphytes frequently occur also on the fronds of the *Laminariaceæ*, especially in the upper portion of the *Laminaria*-belt. Here the brown algæ predominate, while only a few red and green



algæ occur. The following species are common or, at least, occur very socially: —

<i>Chantransia Alariæ.</i>	<i>Myrionema Corunnæ.</i>
<i>Rhodochorton membranaceum.</i>	<i>Phæostroma pustulosum.</i>
<i>R. penicilliformis.</i>	<i>Pylaiella litoralis.</i>
<i>Ascocyclus islandicus.</i>	<i>Streblonema Stilophoræ.</i>
<i>Ectocarpus tomentosoides.</i>	<i>Acrosiphonia incurva.</i>
<i>Litosiphon filiformis.</i>	<i>Ulothrix flacca.</i>

All the remaining *Ectocarpus*-species which are found on the stipes occur in addition. Of the species mentioned there are three in particular which grow very socially: *Chantransia Alariæ* covers the entire frond of *Alaria esculenta* from tip to base; *Ectocarpus tomentosoides* also grows very socially on the fronds of *Laminaria hyperborea* and *L. digitata* which it frequently, entirely or nearly, covers during spring-time, at which time, also, *Litosiphon filiformis* often covers large portions of the lamina of *L. saccharina*.

*Myrionema Laminariæ* and *Streblonema æcidiodes*, in addition, grow as endophytes in the *Laminaria* fronds.

Thus, at least 62 species of marine algæ, or about 59 % of the algal species (113) which grow below the limit of low-tide, occur on or in *Laminariaceæ*.

On other coasts, those of the Færøes, for example (Börjesen, 11 and 12), and those of Norway (Boye, 10) a similar epiphytic vegetation occurs in the *Laminaria*-association. On the coasts of Greenland (Rosenvinge, 63) the epiphytic vegetation is much scarcer in the *Laminaria*-belt, which is possibly due, in part, to the absence of *Laminaria hyperborea* from that country.

### 15. The *Desmarestia*-association.

*Desmarestia aculeata* is very common and grows both scattered and socially; vertically it is widely distributed, as it has been found at depths of from 4—60 metres (in E. Iceland). It seems to grow most luxuriantly at a depth of about 6—30 metres, and then is frequently found in associations of lesser extent. Only rarely is this association found dominant on the bottom, and even then only in small patches. Most frequently it occurs intermingled with other associations; thus, when dredging on a *Laminaria* bottom, it very frequently happens that *Desmarestia aculeata* is brought up, and as frequently as not it is intermingled with the associations which extend deeper down. It often grows among the *Laminariæ*,



where there are openings in the *Laminaria*-vegetation, and beyond the *Laminaria*-belt it is very frequently found on a sandy or pebbly substratum, at any rate at inconsiderable depths. In the *Laminaria*-belt proper it plays the rôle of a kind of "underwood," but beyond the belt, at greater depths, it protrudes far above the associations of red algæ.

*Desmarestia viridis* occurs in a similar manner, very often with the other species, both inside and outside the *Laminaria*-belt. It is of less importance, however, as it is much less common. At depths of between 20--30 metres it may also occur dominantly in patches.

In E. Iceland, at a depth of 20—30 metres, *Chorda tomentosa* occurs growing very socially with the *Desmarestia* species.

Of the epiphytes on *Desmarestia aculeata* the small *Porphyropsis coccinea* is of most importance (in S. and SW. Iceland).

In several respects this association recalls the semi-littoral *Chorda*-association.

Similar *Desmarestia*-vegetation occurs in the Færøes (Börgesen, 14), in Greenland (Rosenvinge, 63) and in northern Norway (Foslie, 18, p. 100).

## 16. The Deep-water Community of Florideæ.

A mixed society, which consists mainly of a few species of red algæ, generally occurs at a depth of about 15—40 metres (over 50 metres in E. Iceland). To judge from the dredgings, the plants sometimes seem to grow socially — at any rate over small areas — and sometimes to grow scattered, then, as a rule, much intermingled with one another.

The species which seem to have an abundant local distribution in fairly many places are the following: *Delesseria sinuosa* at depths of from 14 to nearly 40 metres and somewhat deeper in E. Iceland; *Ptilota plumosa* from 16 metres to about 40 metres; *Odonthalia dentata* from 15—30 metres, and *Polysiphonia arctica* from 16—40 metres (10 to about 60 metres in E. Iceland). Thus each of these species forms associations, but these are often of inferior extent, with the exception, however, of that formed by the last mentioned species.

The *Polysiphonia arctica*-association. *Polysiphonia arctica* is of extremely social growth in E. Iceland, in Seyðisfjörður and in Reyðarfjörður. It grows most luxuriantly at depths of from 16—40 metres and forms an enormous, continuous belt along large

stretches of the coast. It is the only species of this community which forms a large, continuous and almost pure association, at any rate over considerable areas. The upper part of the association is, however, generally mixed with *Delesseria sinuosa*, *Ptilota*, *Odonthalia*, *Rhodophyllis* and others, and then these species often occur in such abundance that the community acquires its usual mixed character; that is, several species occur dominantly side by side, though no single species can be said to predominate.

Among the remaining species of the community *Rhodophyllis dichotoma* is often rather social. It is very common for *Euthora cristata* to occur intermingled, but to judge from the dredgings it seems to have a scattered growth. *Ptilota pectinata* may be of fairly social growth in E. Iceland. *Delesseria sanguinea* and *Polysiphonia urceolata* occur also in this community, the first mentioned appearing to be most frequent while, in a few places, the latter has been found in abundance.

Of the species with a scattered growth which belong to this community may be mentioned: *Lomentaria clavellosa* (20—40 metres), *L. rosea* (20—40) and *Plocamium coccineum* (20 metres), all in the Vestmannaeyjar; and also *Turnerella Pennyi* and *Omphalophyllum ulvaceum* in E. Iceland.

In many places the under-vegetation of the community is formed of crustaceous species of *Lithothamnion*.

Of the intermixed species, *Desmarestia aculeata* and *D. viridis* are very frequent. In E. Iceland *Chorda tomentosa* has been found intermingled in this community. In addition, *Laminariaceæ* of scattered growth such as *Laminaria hyperborea*, *L. digitata*, *L. saccharina*, *Alaria esculenta*, *f. pinnata* and *Alaria Pylaii* occur very frequently; they are the outposts of the *Laminariaceæ*-community.

It has been previously mentioned that many of the members of this community grow on *Laminaria* stems, and that in several places the community forms, together with species of *Desmarestia*, the second layer of the under-vegetation of the community of *Laminariaceæ*.

The community grows both on somewhat exposed and also on exposed coasts, and occurs both on a rocky and on a pebbly substratum, and even on sand.

The semi-littoral *Polysiphonia urceolata*-association has much in common with this community.

Rosenvinge (63) and, following him, Børgesen (12) call this

community or quite similar communities: the sublittoral *Florideæ*-formation.

### 17. The *Lithothamnion*-association.

In this association I include only the highly branched species, *Lithothamnion Ungerii* and *L. tophiforme*, as these differ from the other calcareous algal vegetations by their characteristic and very social growth. Within the fjords, at a depth of about 12—25 metres, these algæ occur in such abundance that there might be good reasons for calling it a submarine reef of calcareous algæ. Within Arnarfjörður in the vicinity of Bildudalur there was, for instance, such a luxuriant vegetation of *L. Ungerii* that the dredging-bag was filled time after time, nothing being found in it save this species. Mr. B. Sæmundsson has also found a similar *Lithothamnion* vegetation in several of the small fjords at Isafjarðardjúp; and as, moreover, there are specimens to hand from several other fjords in NW. Iceland, this association seems to be luxuriantly and commonly distributed in this part of the country. A similar vegetation, mainly composed of *L. tophiforme*, occurred also in abundance in Eyjafjörður in N. Iceland. I have also noticed a similar vegetation — though not so luxuriant — in several of the fjords of E. Iceland. Hörring collected *L. tophiforme* in Hvalfjörður in SW. Iceland, and Sæmundsson also found it there, apparently growing very socially.

In this association very few epiphytes occur, though *Turnerella Pennyi* ought to be mentioned in N. and E. Iceland; on the other hand animals generally occur in abundance, especially *Ophiurida* and snails and other smaller molluscs which project everywhere from between the *Lithothamnion*-branches.

When dredging on such a bottom rather large pieces are hauled up, which cohere, usually, by reason of the numerous branches being matted together. Rather large globular masses, which are sometimes hollow, but which are often filled with comparatively thick interwoven branches, are also frequently obtained. The hollow masses must be supposed to have grown on the outer side of some substratum which has disappeared. This *Ægagropila*-form is generally known. Rosenvinge mentions it from Greenland, and assumes that it lies loose upon the bottom; the masses must then be illuminated all round by being rolled about as, for instance, by the action of the undercurrent. From what I have seen, it seems to me that a point of attachment can be perceived on entirely fresh

forms of *Ægagropila*, and in my opinion they are outgrowths upon old "blocks" of calcareous algæ. The action of the current probably loosens them, and they then roll about on the bottom. Undoubtedly they can live fairly long in that condition, but if they roll about much, they will surely by degrees go to pieces.

This association recalls the semi-littoral *Corallina*-community, particularly the *Corallina*-association.

The *Lithothamnion*-association occurs in Greenland (Rosenvinge, 63) but not at the Færøes (Börgesen, 12).

### 18. The Community of Crustaceous Algæ.

The characteristic life-form of the crustaceous algæ which is so essentially different from that of the rest of the marine algæ seems to justify the idea that they all belong to one community. With all of them the thallus is flat and, like the crustaceous lichens on the rocks, adheres by the whole of its lower surface to the substratum. As the form and the manner of development of the thallus in the different species are identical in their main features, I think that the community may appropriately be named after the crustaceous growth.

The substratum of the community consists of rocks, pebbles, mussel-shells and the like; also of other algæ, especially species of *Laminaria*.

The community has a very large distribution both in a horizontal and in a vertical direction, and possibly it is more particularly members of this community which we may expect to find in the vicinity of the absolute depth-limit of growth of algal vegetation. The community has already been mentioned as the under-vegetation in the *Laminariaceæ*-community; it occurs also as an undergrowth in communities which extend to a greater depth and thus, partly as a dominant growth on the bottom and partly as undergrowth, it reaches from the great depths right up to the limit of low-tide. The semi-littoral and the littoral crustaceous alga-associations should also be regarded as part of this community although, for practical reasons, they have been dealt with earlier in this paper. The community is pure, that is to say it is composed of only crustaceous algæ; there occur, it is true, various intermingled species, of which the majority are *Florideæ*, though some are *Phæophyceæ*, but these I consider unessential and almost irrelevant to the crustaceous alga-community proper. They have their homes in other communities,



and sometimes, perhaps, are in the act of forming an upper vegetation; sometimes they may be individuals which have "strayed" beyond the real limits of their community.

The community is divided into various associations, according as to whether the one or the other of the species is dominant over considerable areas. A widely distributed and typical *Phymatolithon-polymorphum*-association occurs, thus, in S. Iceland, and *Lithothamnion Lenormandi* has a fairly social growth at Reykjavík. *L. læve* and *Clathromorphum compactum* also form associations in several places. Judging from the dredgings, *Lithothamnion flavescens* and *L. foecundum* have a more scattered growth while, on the other hand, *L. glaciale* often occurs abundantly. Otherwise, it is very common for the *Lithothamnion* species to grow intermingled with, and at times upon, one another. The crustaceous, calcareous algæ form the greater part of this community in Iceland. The remaining crustaceous species, such as *Peyssonellia*, *Cruoria arctica* and *Lithoderma fatiscens*, are found more scattered, although the last-named species forms associations in shallow water right up to the limit of low-tide. These species must, however, be much more common on the sea-bottom than is shown by the dredgings. It may be taken for granted, also, that *Petrocelis Hennedyi* and *Rhododermis parasitica* occur on a stony substratum in deeper water, seeing that they are so common on the stems of *Laminaria hyperborea* at considerable depths. Both *Hildenbrandia* and *Petrocelis* occur on a stony substratum at shallower depths, and also *Ralfsia ovata*.

The species which has, with absolute certainty, been found growing deepest is *Lithothamnion læve* (see Part V), and it occurs in masses at a depth of 88 metres, that is, it forms a *Lithothamnionetum* at this depth. Thus, of all the marine algal communities in Iceland, this community extends deepest.

A similar vegetation occurs in Greenland (Rosenvinge, 63, p. 223), and in other places in the Arctic Sea (Kjellman, 36), but in both these places it differs in the wider distribution and greater luxuriance of the *Lithoderma fatiscens*-association. In the Færøes (Börgesen, 12) the conditions seem to be somewhat similar, similar in any case to the conditions in S. and SW. Iceland, although *Lithoderma fatiscens* seems to occur there more sparsely than in Iceland.



## B. The Sea-grass Vegetation.

### The *Zostera*-association.

This association differs so much from the other marine communities in Iceland — the marine algal communities — that it must be regarded as not being in any way connected with them. The present community occurs especially on a substratum of muddy clay, which the algæ avoid. The “roots” of the algæ — the haptera — are organs of attachment only, their sole function being, in most cases, to attach the plant to the substratum — the stony substratum —, while *Zostera* has true roots which obtain nourishment from the substratum. For this reason *Zostera* requires a good nutrient substratum which is generally soft. It is rare, indeed it must be reckoned exceptional, for *Zostera* to be found growing on a hard clay-substratum. I understand such cases to indicate that formerly the substratum had been softer and then became more compact owing to the deposition of clay and sand, and that the *Zostera* is consequently about to disappear from such a spot. In places where there is no danger of either sand or clay being deposited from brooks or rivers the substratum will, nevertheless, scarcely remain unchanged, as the mud and ooze which are thrown down everywhere in the ocean, when once they have been brought to a place, readily accumulate and remain, in the shelter of the dense vegetation.

The *Zostera*-vegetation occurs widely distributed, especially in SW. Iceland where, in many places, both inside the smaller arms of the fjords and in the large fjords such as Breiðfjörður, a substratum of muddy clay occurs between the coast and the skerries which lie nearest. At Breiðfjörður, during low-tide, the pale-green *Zostera*-belt may be observed stretching for miles along the coast. At Faxaflói also the *Zostera*-vegetation has an extensive distribution. *Zostera* is found, most certainly, on other parts of the coast of Iceland, but nowhere have I seen such extensive “meadows” of it as in SW. Iceland.

The vegetation is generally pure and there is hardly an association of species in the sea off these coasts which is less mixed than the *Zostera*-association. In other places *Zostera* is a favourite substratum for epiphytes, but however much I searched I did not find anything worth mentioning on the *Zostera* plants here; in this respect the *Zostera*-meadow of Iceland agrees with that of the Færøes. At times, species belonging to the semi-littoral commu-

nities occur intermingled in the *Zostera*-belt; these then grow in small depressions, where the subsoil, usually a solid, clayey and pebbly substratum, appears. Such species are: *Chorda Filum*, *Chordaria flagelliformis*, *Castagnea virescens*, *Dictyosiphon foeniculaceus*, *Pylaiella littoralis*, *Ceramium rubrum*, *Cystoclonium purpurascens* and others. They should not be classed in the *Zostera*-association, and are mentioned only to explain the appearance of the *Zostera*-meadow.

The *Zostera*-association is sublittoral, but hardly extends as far down as do the semi-littoral communities. It cannot endure protracted exposure, and thus a substratum which would adapt itself well to *Zostera* may be found completely devoid of plants in places which are exposed for a long time during low-tide. From time to time, during extreme ebb-tides, the upper part of the *Zostera*-meadow may, however, be seen quite dry. But here two points have to be taken into consideration: the first being that the period of exposure is extremely short, and the second being that the extreme ebb-tides occur so seldom that they ought not to be taken into calculation. As a rule, the *Zostera* substratum is always submerged during low-tide. The water is so low, however, that the leaves float on the surface of the water, giving it a greenish tinge. When wading in a *Zostera*-meadow during low-tide the water reaches to about the knees.

In SW. Iceland the time of fruiting is during August—October.

On *Zostera*-soil there is in most places a very rich animal-life, but whether this has any influence upon the vegetation or on the nutrient substratum needs further investigation.

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In connection with the *Zostera*-association I will just mention the Brackish-water-vegetation. It is so little known that there is nothing to be said about it, except that I have found *Ruppia maritima* in one solitary spot, where it grew so luxuriantly that, although scattered, it characterized the bottom.

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## VII. DIFFERENCES IN THE VEGETATION IN EAST AND SOUTH ICELAND.

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**E**ast Iceland and South Iceland — at the south-eastern corner of the island, at about the stretch of coast from Vestrahorn to Eystra-horn — are divided by a rather sharp boundary both as regards the hydrography and the composition of the vegetation, as has been mentioned above. On the other hand, E. Iceland is connected with S. Iceland by a large transitional area (see p. 67) which stretches further along the north and north-west coasts and a part of SW. Iceland. The difference as regards the vegetation is therefore greatest between E. Iceland and S. Iceland; so it is these coastal districts which will exclusively or almost exclusively be treated of in this part of the present paper.

Where a great floristic difference exists between the different parts of the coast as, for instance, between E. Iceland and S. Iceland<sup>1</sup> (see Part III) it is to be expected that there will be differences in the vegetation, more especially as some of the species which are not common to all the coastal districts grow socially and form associations. The majority of the communities and the associations are however common to all the districts and are somewhat similar in appearance, as is also seen from the above description (Part VI), where the differences are always mentioned.

As regards the communities and associations common to both districts it is enough to refer to the above description. Here, only those communities and associations will be mentioned which are found in the one district but are absent from the other.

<sup>1</sup> The greater part of the coast of S. Iceland is a sandy coast or a barren "desert;" in this part of the present paper, by S. Iceland is meant only that part of the coast where vegetation occurs — the Vestmannaeyjar and the stretch of coast from Reykjanes in the direction of Thjorsa or somewhat more to the east than Stokkseyri.

Occurring in E. Iceland  
and absent from S. Iceland.

Arctic Associations.

The *Monostroma groenlandicum*-  
association.

The *Polysiphonia arctica*-associa-  
tion.

Subarctic Association.

The *Laminaria feröensis*-associa-  
tion.

Occurring in S. Iceland  
and absent from E. Iceland.

Boreal Communities and Asso-  
ciations.

The *Pelvetia-Fucus-spiralis*-belt.

The Community of *Corallina*.

The *Fucus serratus*-association.

The *Phymatolithon-polymorphum*-  
association.

Further it should be pointed out that the epiphytic vegetation on *Laminaria hyperborea* is quite infinitesimal in E. Iceland, but very luxuriant in S. Iceland.

Of E. Iceland species which are important to the vegetation, *Laminaria nigripes*, *Turnerella Pennyi* and others are absent from S. Iceland. Of S. Iceland species which play a prominent part in the vegetation a great many are wanting in E. Iceland (see Part III).

The *Zostera*-association requires to be described separately. It belongs properly to SW. Iceland. *Zostera* is also known to occur in E. Iceland and it is possible that it forms associations there, but they are probably far more limited in extent than those in SW. Iceland. *Zostera* has not been found in S. Iceland itself, which is probably due to the fact that a favourable substratum for it is wanting there.

If we now leave the *Zostera*-association out of consideration, as the latter does not occur in S. Iceland, and confine our attention to the above-mentioned communities and associations which are found in the one district but are absent from the other, then it is seen that at any rate some of them characterize the vegetation to a considerable extent.

The *Monostroma groenlandicum*-association, as already mentioned, is peculiar to E. Iceland and has a considerable extension in several places there. It is not found in S. Iceland. *Monostroma groenlandicum* occurs sparingly both in N. Iceland and NW. Iceland, therefore it is possible that this association is not exclusively confined to E. Iceland. As the community of filiform algæ is commonly distributed both in E. and S. Iceland and green filiform algæ occur very luxuriantly in S. Iceland, the absence of *M. groenlandicum* from the latter place is of no essential importance to the vegetation as regards appearance.

The *Polysiphonia arctica*-association is of importance as regards the appearance of the sublittoral vegetation in E. Iceland. This association does not occur in S. Iceland, but a corresponding one occurs, which is however far less luxuriant, composed of *Polysiphonia urceolata*.

The *Laminaria færøensis*-association is known to occur only in E. Iceland. This association is probably more widely distributed along Iceland than is at present known; the species occurs at any rate in N. Iceland. But I think that this species will hardly be found along the coast of S. Iceland owing to the fact that sheltered localities are wanting there.

The *Pelvetia-Fucus-spiralis*-belt is most commonly distributed in S. and SW. Iceland, and composes there the upper part of the *Fucaceæ*-community. As this belt is absent from E. Iceland there is a considerable difference in the appearance of the uppermost part of the *Fucaceæ*-community in the coastal districts in question. *Fucus spiralis* is, however, found in E. Iceland.

The Community of *Corallina* is also peculiar to S. and SW. Iceland and absent from E. Iceland. This community, or the *Corallina-Gigartina* belt, is very luxuriant and often of considerable extent in S. Iceland (and SW. Iceland), owing to which the semi-littoral vegetation in E. Iceland and in S. Iceland differs highly in character.

The *Fucus serratus*-association is poorly represented in S. Iceland, but it is luxuriant in a single locality in SW. Iceland. As *Fucus serratus* is rare, and somewhat resembles in appearance the large, broad-leaved forms of *Fucus inflatus* which are common everywhere, it plays only an inconsiderable part as regards the appearance of the *Fucaceæ*-community.

The *Phymatolithon polymorphum*-association is peculiar to S. Iceland, but as other crustaceous, calcareous algæ occur in E. Iceland in a similar manner though less luxuriantly, the absence of *Phymatolithon polymorphum* is of no essential importance as regards the appearance of the crustaceous-alga-vegetation.

From what has been stated above it is evident that the occurrence of the *Pelvetia-Fucus-spiralis*-belt and the *Corallina-Gigartina*-belt in S. Iceland (and SW. Iceland) gives to the littoral and semi-littoral vegetation of the southern district a character different from that of E. Iceland.



If we now turn to the individual species which (besides those already mentioned) are found in the one coastal district but are absent from the other, and which are important as regards the appearance of the vegetation, we see, as already mentioned, that such species are few in E. Iceland and numerous in S. Iceland. Some of these species have a fairly social growth without, however, forming independent associations. In the following, only those species are given which occur most abundantly.

#### East Iceland.

*Lithothamnion flavescens*.  
*L. foecundum*.  
*Laminaria nigripes*.  
*Turnerella Pennyi*.  
*Ptilota pectinata*.  
*Peyssonellia Rosenvingii*.  
*Coilodesme bulligera*.  
*Ulothrix consociata* var. *islandica*.

#### South Iceland.

*Lomentaria clavellosa*.  
*Plocamium coccineum*.  
*Chantransia Alariæ*.  
*Callithamnion Arbuscula*.  
*Plumaria elegans*.  
*Ceramium acanthonotum*.  
*C. rubrum*.  
*Polysiphonia fastigiata*.  
*Rhododermis parasitica*.  
*Cystoclonium purpurascens*.  
*Ptilota plumosa*.  
*Petrocelis Hennedyi*.  
*Ectocarpus fasciculatus*.  
*E. tomentosus*.  
*Cladophora rupestris*.  
*Enteromorpha Linza*.

It should moreover be noted that all the *Ceramium*-species are absent from E. Iceland. In S. Iceland, besides those mentioned above, *Ceramium allanticum* occurs, and it will no doubt be possible to find several more *Ceramium*-species in S. Iceland.

The Epiphytic Vegetation on *Laminaria hyperborea*, as mentioned several times, is very luxuriant in S. and SW. Iceland; in NW. and N. Iceland it must also be said to be fairly luxuriant, but in E. Iceland it is quite infinitesimal in amount, which is probably connected with the fact that *Laminaria hyperborea* is rare in E. Iceland.

The epiphytic vegetation on the stipes of *Laminaria hyperborea* is very luxuriant and finely developed in S. Iceland. The following from the Vestmannaeyjar are given as an example: — dominantly on the stipe of *L. hyperborea* occurred *Rhodymenia palmata*, *Delesseria alata* and *Plocamium coccineum*; less abundantly than the three above-mentioned species occurred *Delesseria sanguinea*, *Lomentaria clavellosa*, *Lomentaria rosea*, *Euthora cristata*, *Gigartina mamilliosa*, *Ahnfeltia plicata*, *Petrocelis Hennedyi*, *Dermatolithon macrocarpum* and

*Pterosiphonia parasitica*. To show how rich in species the epiphytic vegetation occurring on a single individual of *L. hyperborea* may be, the following species, also from the Vestmannaeyjar, may serve: *Desmarestia viridis*, *Ptilota plumosa*, *Delesseria sinuosa*, *Delesseria alata*, *Lomentaria clavellosa*, *Polysiphonia urceolata*, *Plocamium coccineum*, *Delesseria sanguinea* and *Euthora cristata*.

So luxuriant and finely developed an epiphytic vegetation gives to the *Laminariaceæ*-community of S. Iceland a character different from that which it has in E. Iceland.

On the stipes of *Alaria* and *Laminaria digitata*, on the other hand, a similar epiphytic vegetation occurs in both the coastal districts.

The zonal division of the marine algal vegetation is in its main features similar in E. Iceland and S. Iceland, as is shown by the following examples which have been taken straight from the diaries.

#### East Iceland.

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|--|---|
| <p>Vattarnes, steep cliffs,<br/>highly exposed. <sup>14</sup>/<sub>7</sub>.</p> <p>I. Ulothricetum U. flaccæ.</p> <p>II. Bangietum B. fuscopurpureæ.</p> <p>III. Porphyretum P. umbilicalis.</p> <p>IV. Fucetum F. inflati, in the most<br/>exposed localities, consisting<br/>only of f. exposita.</p> <p>V. Rhodymenietum.<br/>Halosaccionetum.<br/>Acrosiphonietum.</p> <p>VI. Sublit. Alarietum.</p> <p>Borgarnes, sloping rocky coast,<br/>considerably exposed. <sup>13</sup>/<sub>6</sub>.</p> <p>I. Prasioletum P. stipitatae.</p> <p>II. Ulothricetum U. flaccæ, in great<br/>abundance.<br/>Rhizoclonium in crevices.</p> <p>III. Bangietum B. fuscopurpureæ,<br/>in wonderful abundance.</p> <p>IV. Porphyretum P. umbilicalis, of<br/>great extent.</p> <p>V. Monostroma groenlandicum.</p> <p>VI. Fucus vesiculosus, sparse and<br/>miserable.</p> <p>VII. Fucetum F. inflati, abundantly.<br/>The specimens very variable.</p> | <p>VIII. Halosaccionetum H. ramentacei.<br/>Urospora Wormskioldii.<br/>Polysiphonia urceolata.<br/>Rhodomela lycopodioides.<br/>Chorda tomentosa.</p> <p>IX. Alarietum.</p> <p>Hólmanes, somewhat exposed,<br/>sloping rocky coast. <sup>18</sup>/<sub>7</sub>.</p> <p>I. Ulothricetum U. flaccæ.</p> <p>II. Enteromorphetum E. intestinalis.</p> <p>III. Fucetum, uppermost, narrow<br/>margin of F. vesiculosus, below that,<br/>broad belt of F. inflatus, intermixed<br/>here and there sparsely with Ascophyllum<br/>nodosum.<br/>Under-veg. Hildenbrandietum.</p> <p>IV. Halosaccionetum, intermingled<br/>with Monostroma fuscum, Porphyra<br/>miniata, Rhodymenia palmata and a few<br/>Fucus inflatus.</p> <p>V. Alarietum, composed of Alaria<br/>esculenta and A. Pylaii.</p> <p>VI. Laminarietum L. saccharinae.</p> <p>VII. Laminarietum L. digitatae.</p> |
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## South Iceland.

- Vestmannaeyjar, much exposed, steep, rocky coast. <sup>20</sup>/<sub>5</sub>.
- I. Ulothricetum *U. flaccæ*.
  - II. Porphyretum *P. umbilicalis*.
  - III. Ascophylletum *A. nodosi*.
  - IV. Gigartinetum *G. mamillosæ*, broad belt, in it *Corallina officinalis*, *Ceramium acanthotum*, *Callithamnion*, *Delesseria alata*.
  - V. Corallinetum *C. officinalis*, dispersed in it *Laminariae*.
- Vestmannaeyjar, Víkin, considerably exposed, sloping rocky coast. <sup>21</sup>/<sub>5</sub>.
- I. Ulothricetum *U. flaccæ*.  
Enteromorphetum *E.\* micrococcae*.  
*Acrosiphonietum*.
  - II. The Fucus-belt.  
*Ascophyllum nodosum*.  
*F. vesiculosus*.  
*F. inflatus*.
  - III. Gigartinetum }  
*G. mamillosæ* } floating
  - IV. Corallinetum } together.  
*C. officinalis* }
  - V. Laminarietum *L.\* stenophyllæ*.
  - VI. Alarietum *A. esculentæ*.
  - VII. Laminarietum *L. hyperboreæ*.

Vestmannaeyjar, the skerry, considerably exposed, sloping rocky coast almost destitute of phanerogams. <sup>18</sup>/<sub>5</sub>.

- Uppermost, *Cochlearia officinalis* and rosettes of *Plantago maritima*.  
At the same level, in crevices:
- I. Enteromorphetum *E.\* micrococcae*, + *Cladophora sericea*.
  - II. Ulothricetum }  
*U. flaccæ* } on flat rocks  
*Prasioletum* } between  
*P. stipitatae* } crevices.
  - III. *Pelvetia canaliculata*.
  - IV. *Fucus spiralis*.
  - V. Ascophylletum *A. nodosi*.  
*F. vesiculosus*.  
*F. inflatus*.  
Under-veg. *Callithamnionetum*.  
*Antithamnion*.  
*Gigartina*.
  - VI. Gigartinetum  
*G. mamillosæ*.
  - VII. Laminarietum  
*L.\* stenophyllæ*.  
Under-veg. *Phymatolithon polymorphum*.

South Iceland, south side of Reykjanes,  
according to C. H. Ostenfeld's diary.

- Staður, wide foreshore, considerably exposed. <sup>12</sup>/<sub>6</sub>.
1. *Pelvetia canaliculata*.  
+ stunted *F. vesiculosus*.
  2. *Fucus spiralis*, with stunted  
*Ascophyllum* and  
*Cladophora rupestris*.
  - 3.a *Ascophyllum* + *Polysiphonia fastigiata*, broad belt.
  - 3.b *Fucus vesiculosus* formation,  
in it *F. inflatus*, widely distributed,
  - 3.c in it *Gigartina*.
  4. Here and there in depressions  
the formations:  
*Monostroma Grevillei* and  
*M. fuscum*.

- + *Halosaccion*.  
*Cystoclonium*.  
*Ahnfeltia*.  
*Dictyosiphon foeniculaceum*.  
*Rhodymenia*.
5. *Laminaria* + *Alaria*.

The foreshore between Staður and Reykjanes. <sup>13</sup>/<sub>6</sub>.

1. Uppermost, *Porphyra umbilicalis*.  
*F. spiralis*.  
*F. vesiculosus f. sphærocarpa*.  
*Enteromorpha compressa*.
2. *F. inflatus*-formation, widely distributed and in it *Gigartina*.

- |  |   |
|--|---|
| 3. <i>Gigartina</i> , widely distributed.<br><i>Rhodymenia</i> .<br><i>Plumaria elegans</i> .<br><i>Delesseria alata</i> .<br><i>Acrosiphonia</i> .<br><i>Monostroma Grevillei</i> .<br><i>Chætomorpha Melagonium</i> .<br><i>Delesseria sanguinea</i> and others. | 4. <i>Corallina</i> widely distributed, in<br>a single pool <i>Halosaccion</i> .<br>5. <i>Laminaria</i> + <i>Alaria</i> . |
|--|---|

In another part:  
*Ascophyllum* in quantities between  
 1 and 2.

It would carry us too far to give several more examples from the diaries, but on regarding the material taken as a whole it is distinctly seen that there is no other difference of importance between the two districts with regard to the zonal division of the algal vegetation beyond the fact that some of the communities and associations occur in one place and are absent from the other. The division of the belts varies somewhat in both places which is chiefly due to the greater or smaller degree of exposure of the locality (see Part VI).

The most conspicuous difference in the division of the belts in E. Iceland and S. Iceland is due to the enormous size of the *Corallina*-belt in the latter place. This community (*Gigartina*, *Corallina* and others; see Part VI) occurs just below the *Fucus*-belt where, for instance, in the Vestmannaeyjar it is the dominant one; this also applies to Eyrarbakki and the south side of Reykjanes, but perhaps to a somewhat less degree. This leaves less room for the *Rhodymenia*-community (*Rhodymenia*, *Halosaccion*; see Part VI), which also forms a belt below the *Fucus*-belt; consequently it is not so large there as in E. Iceland where it is extremely common and in several places widely extended. In many places in SW. Iceland the *Rhodymenia*-community is as large as in E. Iceland.

The sea off the coast of S. Iceland is in movement everywhere, and calm water is almost unknown. The calm-water-vegetation proper, which is so common within the fjords of E. Iceland, is therefore absent from S. Iceland, but is again found richly represented in SW., NW. and N. Iceland.

The luxuriancy of the vegetation is somewhat similar in both places; it appears, however, to be greater in the Vestmannaeyjar and the western part of the south coast.

Depth-limit. It appears that there is reason to believe (see Part V) that the algal vegetation extends to greater depths in the fjords of E. Iceland than on the south coast, but as this cannot be regarded as sufficiently proved I shall not enter into it more fully.

## VIII. SOME NOTES ON THE BIOLOGY OF THE ALGÆ ALONG THE COAST OF ICELAND.

AT present very little is known with regard to the biology of the marine algæ along the coast of Iceland. What is known, on the whole, regarding this point is for the most part mentioned in the "Marine Algæ of Iceland" (31) under each species. Some observations which have been made subsequently will be mentioned in the following pages. Of these, I regard those which have been made during winter as the most important, although they are very incomplete owing to the fact that during winter I have only rarely been able to make investigations, and then have had access to the littoral zone only; thus, with the exception of a few species, the winter-habit of the sublittoral species is not known. Consequently I can, by no means, treat of the biological conditions exhaustively, but must content myself with giving a few incomplete contributions.

On the whole, the behaviour of the species is best known in spring and summer, less well in autumn, and least well during winter. From most of the coastal districts there are observations to hand either only those of a single season of the year, or at most of two or three seasons. From Reykjavík we have observations of all four seasons, but those of the winter are sparse, and only a few species have been observed throughout the year.

The observations to hand are so few and insufficient that a comparison of the biological conditions in the five coastal districts in question cannot be made; here, therefore, Iceland is treated for the most part as an entirety.

### 1. Duration of Life.

The life-period of the algal species is of very varying length; in this connection the algæ may be divided into two groups: annual algæ and perennial algæ.



A. Annual algæ. The annual species are especially the Green Algæ which grow in the upper littoral zone and are exposed during each low-tide. The upper littoral zone is that part of the algal region where the change of seasons is most felt and where winter prevents many species from continuing life. Such species then produce spores which live through the winter as such, or in the early stages of germination. Of annual species the following may be mentioned: —

<i>Codiolum gregarium.</i>	<i>Ulothrix</i> -species.
<i>C. pusillum.</i>	<i>Ulvella.</i>
<i>Percursaria.</i>	<i>Pringsheimia.</i>
<i>Enteromorpha</i> -species.	<i>Urospora</i> -species.
<i>Monostroma</i> -species.	<i>Chætomorpha tortuosa.</i>
<i>Prasiola</i> -species.	<i>Spongomorpha vernalis.</i>
	<i>Cladophora</i> -species.

In addition, some of the endophytic species must be regarded as belonging to the annuals, although some of them can be met with at all seasons of the year. As examples of such species may be mentioned: — *Chlorochytrium*-species and *Codiolum Petrocelidis*.

The life-periods of the species mentioned above are probably of different lengths and it is possible that some of them can produce several generations during one summer (cf. Börgesen, 11 and 12). The majority of these species grow luxuriantly during spring (March—May) and summer (June—August), produce spores at the end of summer and then die. Some of them, however, continue life into the autumn (September—November), or at any rate until September. A few may also be met with during winter (December—February), e. g. *Enteromorpha intestinalis* f. *prolifera*, *Monostroma fuscum* (sterile and fruiting), *Cladophora rupestris* (abundantly) and *Cladophora sericea* (sparingly).

Of the above-mentioned endophytic species I shall refer to *Chlorochytrium inclusum* and *Codiolum Petrocelidis* only. Both these species occur at all seasons of the year. They are found most frequently in the host-plants in the sublittoral zone, where the conditions of life must be considered to be more stable than in the littoral zone. I regard such species as short-lived. They are found all the year round, as probably several generations are produced during the year.

Among the annual Brown Algæ the following must be included: — *Myrionema*-species, *Ascocyclus* and the majority of the *Ectocarpaceæ*, *Leptonema*, *Litosiphon*, *Isthmoplea*, *Phæostroma*, *Ca-*

*stagnea* and *Leathesia* (living from June to September). In addition there are species which may be supposed to be annual, as for example, *Punctaria*, *Stictyosiphon*, *Scytosiphon* (?), *Phyllitis*, the majority of the *Dictyosiphonaceæ*, *Chorda*-species, etc.

Of Red Algæ the following must be presumed to be annual:—*Bangia*, *Porphyra*-species, *Porphyropsis*, *Conchocelis*, *Chantransia*-species, *Ceramium*-species and possibly several more. As regards *Porphyra umbilicalis* it should, however, be stated that it has been found at all seasons of the year and at Reykjavík it occurs as luxuriantly in December—January as during the spring.

B. Perennial Algæ. With regard to some of the species it is difficult to decide whether they are perennial or annual, as our knowledge of them is incomplete; consequently it is sometimes a matter of opinion whether they are to be included in the one or in the other group. Only a few of the Green Algæ are perennial, as for instance, the majority of the *Acrosiphonia*-species. The latter, besides being reproduced by spores, have also abundant vegetative reproduction by means of offshoots; and some of them, as for instance, *A. albens* and others, live all the year round in the semi-littoral zone.

Of the Brown Algæ the *Fucaceæ* and the *Laminariaceæ* are perennial. It is, however, doubtful whether we are justified in including *Saccorhiza dermatodea* among the perennials. At Reykjavík I have seen only old fruiting specimens in the winter, and judging from their appearance it is very probable that they die during the winter; nothing can, however, be stated with certainty regarding this point.

In the fjords of E. Iceland large individuals of this species were growing in the sublittoral zone; I believe they were more than one year old, but I could not prove this. In Greenland (Rosenvinge, 61, p. 852) perennial or upwards of a year old individuals of this species occur.

With regard to several other species of Brown Algæ it is not easy to say at present whether they are annual or perennial. I think, however, that the following may be classed as perennial:—*Lithoderma*, *Ralfsia*-species, *Sphacelaria*-species, *Chætopteris*, *Desmarestia aculeata*, *D. ligulata*, *Chordaria flagelliformis* (?).

I think that the majority of the Red Algæ are perennial or can, at any rate, live through more than one growth-period. I shall,

in the following, name some species which I am fairly certain may be included among the perennials: —

Gigartina mamillosa.	Halosaccion ramentaceum.
Ahnfeltia plicata.	Polysiphonia urceolata.
Euthora cristata.	Rhodomela lycopodioides.
Rhodophyllis dichotoma.	Odonthalia dentata.
Rhodymenia palmata (?).	Ptilota plumosa.
	Rhodochorton Rothii.

The crustaceous algæ such as *Hildenbrandia*, *Petrocelis*, *Cruoria*, *Peyssonellia* and *Rhododermis*, and by far the greater number of the calcareous algæ must also be classed as perennial.

## 2. Periodical Changes.

The Period of Activity. The Period of Rest. The period of activity of the annual species is identical with their period of life and it extends, probably as regards the majority of the species, over the spring and summer months. The perennial species and the species which can live more than one year, have a very long period of activity which extends over the greater part of the year with the exception of the darkest part; consequently these species have a very short period of rest. Although from the observations to hand it is not possible to fix the length of the period of rest, yet they indicate that it must be short. The *Fucaceæ* may be mentioned as an example. Their vegetative growth appears to be very slight during December—January, and in the case of the older individuals there is probably none at all at that time; but although the majority of the individuals of the *Fucaceæ* are sterile during winter yet, even in December, reproductive organs are developing here and there. Young plants of the summer or autumn appear to have vegetative growth also during the winter. In the *Fucaceæ*-belt, taken as a whole, the period of rest is consequently extremely short. In the sublittoral zone I think that entire rest must be of extremely short duration.

Renewal of the lamina. The young shoots. As is well known, a renewal of the lamina takes place yearly in the *Laminaria*-species. At what time this takes place in Iceland cannot be stated with absolute certainty, but the observations seem to indicate that the new lamina begins to grow even in the winter time, as the light increases. I believe that in SW. Iceland a general renewal of the

lamina takes place in February—March. In April individuals with large, new laminæ, with the old laminæ or portions of them still attached, are frequently found at Reykjavík, but the majority of the *Laminaria* individuals have renewed their laminæ by that time. A few individuals are however met with until June in SW. Iceland in the act of lamina-renewal. With regard to some of the most common species the following may be noted: —

*Laminaria saccharina* in SW. Iceland (1897) was frequently found in the lamina-renewal stage in April, while some individuals were renewing their laminæ in May. *Laminaria digitata*: some individuals were renewing their laminæ in April and until June in SW. Iceland (1897). *Laminaria hyperborea* in SW. Iceland (1897), some were renewing their laminæ in May—June.

*L. hyperborea* was found renewing its laminæ in July on the north coast of Iceland. This was observed only once, therefore it cannot be concluded from this that the lamina-renewal stage commences later or lasts longer on the north coast than in SW. Iceland.

In the Færøes (Börgesen, 11 and 12) the lamina-renewal stage occurs at the same time as in SW. Iceland.

On the west coast of Sweden the renewal of the lamina takes place during winter (Kylin, 45) and in *Laminaria saccharina* and *L. digitata* the young leaf, in December, is a quarter the size of the old one; in April it is only exceptionally that individuals are found with a portion of the old lamina attached. The renewal of the lamina in *L. hyperborea* takes place later, and in April the new lamina is a quarter the size of the old one, and in the beginning of July a portion of the old lamina is still present.

In connection with the lamina-casting species the following may be mentioned: —

*Desmarestia aculeata* has been collected bearing the brown, as-similatory hairs in March—May in SW. Iceland, in May in NW. Iceland, in June in E. Iceland, and in July in N. Iceland. This appears to indicate that the hair-bearing stage occurs later on the north and east coasts, or that it lasts longer. The species behaves in the same manner in Greenland (Rosenvinge, 61, p. 857) where the hairs are cast off, at the latest, in June in South Greenland, while hair-bearing individuals are found in July and August in North Greenland. In the Færøes it has been observed with hairs upon it in May—June (Börgesen, 13, p. 445), but hair-bearing individuals were, however, rare in June. On the west coast of



Sweden (Kylin, 45) the hairs are cast in June, but (young) hair-bearing individuals may, however, be met with in July.

*Polysiphonia urceolata* has hair-leaves in the spring, summer and beginning of autumn, but individuals without hairs are found side by side with hair-bearing ones from May to August. In December only hairless individuals have been observed at Reykjavík, and in January—February only hairless plants have been collected in N. Iceland.

*Rhodomela lycopodioides* has been collected with hair-leaves in March—July, and hairless in June—August in SW. Iceland; with hair-leaves in April—December, and hairless in July—August in N. Iceland; with hair-leaves in June—July and hairless in May—July in E. Iceland. In the autumn this species had cast off its leaves and branches in SW. Iceland.

In addition to this, the following instances of the occurrence of young shoots may be mentioned: —

*Odonthalia dentata*. The young shoots in this species are readily recognized by their paler red colour. Material from January—February bears young shoots. The latter are easily recognizable in January, and have probably begun to grow out in December. The young shoots then increase in size, and the colour becomes gradually darker month by month. In material collected in June—July the length of the year's shoot may even then be determined in some of the individuals, but I believe, however, that it is in July that the shoot is almost full-grown.

*Polysiphonia fastigiata* has young shoots in December at Reykjavík.

*Odonthalia* shows distinctly the period of development of the vegetative shoots in the sublittoral zone, and I presume it may be taken for granted that the other sublittoral species do not differ very much from it as regards this point.

In Greenland the formation of the new shoots begins in February—March (Rosenvinge, 63, p. 239), and the growth is continued until August or during the whole summer.

In the Færøes the new shoots begin to appear in the latter part of autumn (Börgesen, 12, p. 828).

From Spitzbergen (Kjellman, 36) some sublittoral species are known which form new shoots during the winter, as for instance, *Delesseria sinuosa* in January, and *Rhodymenia palmata* from November to May.



The Fruiting Period. In the table given below is indicated the time at which the species have been found in fruit. A + signifies that the greater part of the individuals in the samples gathered were fruiting; a  $\pm$  signifies that fruiting and sterile individuals occurred in almost equal abundance, or sometimes that only a few fruiting individuals occurred; a — signifies that only sterile individuals of the species were found.

In the majority of the annual species the fruiting period coincides with the vegetative stage, and thus growing vegetative shoots and sporangia are frequently found on the same individual. These species fruit comparatively quickly and the young, or purely vegetative, stage is of short duration. The fruiting period extends over spring and summer probably in the case of the majority of the species. They do not, however, behave similarly in this respect in the different coastal districts. *Urospora Wormskioldii*, *Monostroma Grevillei*, *M. undulatum*, *Ectocarpus tomentosoides* and *Litosiphon filiformis* are all decidedly spring plants at Reykjavík, but in E. Iceland they have been found bearing fruit far into the summer. *Leathesia difformis* is a decidedly summer species at Reykjavík, it has been observed fruiting in June, July, August and even into September, but it was dying away in the middle of September. At Reykjavík its life-period coincides with its fruiting-period, but in N. Iceland it has been gathered in a sterile condition in September. This species appears to behave in the same manner on the west coast of Sweden (Kylin, 45) as at Reykjavík. Moreover the fact may be emphasized that at the latter place *Enteromorpha Linza* is usually a summer and autumn species.

With regard to the perennial species, it happens both that the vegetative growth and the fruit-formation is simultaneous, and also that the two stages occur at different times. A purely vegetative, young stage, more prolonged than in the annuals, is found in several of the perennials; thus, I think that I have seen indications of *Alaria* and *Laminaria* species being in a purely vegetative stage throughout the first year and perhaps longer.

Kylin (45, p. 274) divides the perennial species into three groups according to their life-activity: —

Group 1 includes species which carry on vegetative and reproductive work all the year round.

Group 2. Species which carry on vegetative work the whole year, but reproductive work only for a part of the year.

Group 3. Species which carry on vegetative and reproductive work only during a part of the year.

In referring the Icelandic species to these groups the difficulty at once arises, that we lack knowledge regarding the behaviour of a number of the species during winter. Such species cannot therefore be grouped with any certainty at the present time. True, we may judge with some probability how they behave here during winter by a comparison of their winter-activities in other places, provided these are known; but as it has been shown that one and the same species often behaves differently in two distantly situated places, a satisfactory result could not be arrived at through such a comparison which has, for that reason, been omitted. I therefore mention a few species only, which I think I can group with some certainty.

Group 1. The following species belong to this group: — *Hildenbrandia rosea* which fruits all the year round. *Rhodymenia palmata*; it might appear doubtful whether this species should be classed as a perennial. Kjellman (36, p. 150) regards it as an annual plant which forms tetraspores twice, once as a young plant and the second time just before it dies. It appears to me that the new shoots which arise early in spring from evidently old fronds, show that it lives through at any rate more than one period of growth. *Pelvetia canaliculata* bears fruit and carries on vegetative work the whole year at Reykjavík. In December—January the fruiting individuals were comparatively few, but there was a quantity of young plants almost all of which were in the "rosette" stage. It is perhaps doubtful if this species belongs to this group at all.

Group 2. The *Fucaceæ* belong to this group (with the exception of *Pelvetia* (?)). *Fucus spiralis* produces fruit in spring, summer and autumn. In December (1911) it was sterile, and young plants were found in quantities.

*Ascophyllum nodosum*, *Fucus vesiculosus* and *Fucus inflatus*, all these behave almost similarly. In December and January I saw, here and there, individuals with very young receptacles, but by far the greater part were sterile. In spring and early summer these species are found everywhere with full-grown receptacles. In the latter half of August they are sterile everywhere and at that time only a few individuals, which must be regarded as stragglers, are found bearing receptacles. Of *F. inflatus* I saw no stragglers in August. In September also they are sterile. In the first half of October

both *Ascophyllum* and *F. inflatus* are sterile, but at that time a few individuals of *F. vesiculosus* bear young receptacles. From the middle of October until December there are no observations to hand from Reykjavík. The usual course, with regard to these species, appears to be as follows: In the latter part of the autumn the development of the sexual organs begins, and is continued throughout the winter; in March the species are found everywhere with ripe sexual organs and the spores continue their development until the latter part of the summer.

Kjellman (36, p. 195) records with regard to *Ascophyllum nodosum* in Finmark, that it had numerous receptacles in July and the first half of August, was sterile in the latter part of August, and that new receptacles had begun to appear in October. Foslie (18, p. 64) records with regard to the same species in East Finmark that it has abundant receptacles in July and is sterile in August.

In the Færöes (Börgesen, 12, p. 830) *Ascophyllum nodosum* has young receptacles in December and fruits during the whole summer.

On the west coast of Sweden the sexual organs begin to develop late in August or early in winter (Kylin, 45, p. 106), and by the beginning of June the receptacles have fallen off.

*Fucus inflatus* probably behaves in East Finmark in a similar manner as at Reykjavík. Foslie (18, p. 67) mentions receptacle-bearing individuals in June—July and the first part of August. At Spitzbergen it bears fruit during winter and Kjellman (36, p. 204) found germinating spores in December, January, February and March.

To Group 2 belong, in addition, probably all the *Laminariaceæ*, *Rhodochorton Rothii*, *Polysiphonia urceolata*, *Halosaccion*, *Gigartina mamillosa*, *Odonthalia* and probably many more. *Petrocelis Henedyi* belongs also most nearly to this group; it has been found producing fruit the whole year, but in spring, summer and autumn only a few fruiting crusts are found, while the winter appears to be the ordinary fruiting period. *Chætopteris plumosa* I include, although with doubt, in this group.

Group 3. To this belong *Desmarestia aculeata*, which has been found fruiting in October, *Rhodomela lycopodioides*, *Delesseria sanguinea* and others.

## The Fruiting-period of the Species.

	Spring	Summer	Autumn	Winter
<i>Bangia fuscopurpurea</i> .....	+	+	+	
<i>Porphyra umbilicalis</i> .....	+	+	+	+
<i>P. miniata</i> .....	—	+	+	
<i>Porphyropsis coccinea</i> .....	—	—		
<i>Conchocelis rosea</i> .....	—	—	—	
<i>Chantransia microscopica</i> .....			—	
<i>C. Alariæ</i> .....		+		
<i>C. secundata</i> .....	+	+	+	
<i>C. virgatula</i> .....	+	+		
<i>Chondrus crispus</i> .....	+	+		
<i>Gigartina mamillosa</i> .....	—	+	+	—
<i>Ahnfeltia plicata</i> .....	—	—	—	—
<i>Phyllophora Brodiaei</i> * interrupta.....	—	—		
<i>P. membranifolia</i> .....	—	—	—	
<i>Actinococcus subcutaneus</i> .....	—	—		
<i>Ceratocolax Hartzii</i> .....	+			
<i>Cystoclonium purpurascens</i> .....	—	—	+	
<i>Turnerella Pennyi</i> .....	—	—		
<i>Euthora cristata</i> .....	+	+	+	
<i>Rhodophyllis dichotoma</i> .....	+	+		
<i>Rhodymenia palmata</i> .....	+	+	+	+
<i>Lomentaria clavellosa</i> .....	—	+		
<i>L. rosea</i> .....	—			
<i>Plocamium coccineum</i> .....	+	+	—	
<i>Halosaccion ramentaceum</i> .....	+	+	—	+
<i>Delesseria alata</i> .....	+	+	—	
<i>D. sinuosa</i> .....	+	+	+	
<i>D. sanguinea</i> .....	—	—	+	+
<i>Pterosiphonia parasitica</i> .....	+			
<i>Polysiphonia urceolata</i> .....	+	+	+	—
<i>P. fastigiata</i> .....	+	+	—	+
<i>P. arctica</i> .....	—	+	—	
<i>P. nigrescens</i> .....	—	—	+	
<i>Rhodomela lycopodioides</i> .....	+	+	+	—
<i>Odonthalia dentata</i> .....	—	+	+	+
<i>Callithamnion Arbuscula</i> .....	+	+		
<i>C. scopulorum</i> .....	+	+		
<i>Plumaria elegans</i> .....	+	+	+	—
<i>Ptilota plumosa</i> .....	+	+	+	+
<i>P. pectinata</i> .....	+	+	+	
<i>Antithamnion Plumula</i> * boreale.....	—	+		
<i>A. floccosum</i> .....	+	+		
<i>Ceramium acanthonotum</i> .....	—	—		
<i>C. Deslongchampsii</i> .....		—		
<i>C. fruticulosum</i> .....		+		

## The Fruiting-period of the Species (continued).

	Spring	Summer	Autumn	Winter
<i>Ceramium circinnatum</i> .....		+		
<i>C. arborescens</i> .....		+		
<i>C. atlanticum</i> .....		+		
<i>C. rubrum</i> .....	+	+	+	
<i>Rhodochorton Rothii</i> .....	+	+	—	—
<i>R. repens</i> .....	+			
<i>R. minutum</i> .....		+		
<i>R. penicilliforme</i> .....	+	+		
<i>R. membranaceum</i> .....	+	+		
<i>Dumontia filiformis</i> .....	+	+		
<i>Dilsea edulis</i> .....		—		
<i>Petrocelis Hennedyi</i> .....	+	+	+	+
<i>Cruoria arctica</i> .....	—	+		
<i>C. pellita</i> .....		+		
<i>Peyssonellia Rosenvingii</i> .....	—	—	—	
<i>Rhododermis parasitica</i> .....	+	+		
<i>Lithothamnion glaciale</i> .....	—	—	—	
<i>L. Unger</i> .....	—	—		
<i>L. tophiforme</i> .....		—	—	
<i>L. flavescens</i> .....		—		
<i>L. foecundum</i> .....		—		
<i>L. læve</i> .....	—	—		
<i>L. Lenormandi</i> .....	—	—		
<i>Phymatolithon polymorphum</i> .....	—	—		
<i>Clathromorphum compactum</i> .....	—	—	—	—
<i>Lithophyllum Crouani</i> .....	—	—		
<i>Dermatolithon macrocarpum</i> .....	+	+		
<i>Corallina officinalis</i> .....	—	+	—	
<i>Hildenbrandia rosea</i> .....	+	+	+	+
<b>Phæophyceæ.</b>				
<i>Lithoderma fatiscens</i> .....	—	+	—	—
<i>Petroderma maculiforme</i> .....				+
<i>Ralfsia ovata</i> .....		+	+	
<i>R. clavata</i> .....	+	+	—	+
<i>R. verrucosa</i> .....		+	+	
<i>R. deusta</i> .....	—	—	—	
<i>Myrionema vulgare</i> .....	—	—		
<i>M. Corunnæ</i> .....	+	+		
<i>M. globosum</i> .....	+	+	+	
<i>M. færøense</i> .....	+			
<i>M. Laminariæ</i> .....		+		
<i>Ascocyclus islandicus</i> .....			+	
<i>Microsyphar Polysiphoniæ</i> .....		+		
<i>Streblonema æcidioides</i> .....		+	+	



## The Fruiting-period of the Species (continued).

	Spring	Summer	Autumn	Winter
<i>Streblonema Stilophoræ</i> v. <i>cæspitosa</i> . . . . .	+	+	+	
<i>Pylaiella littoralis</i> . . . . .	+	+	+	—
<i>Ectocarpus tomentosoides</i> . . . . .	+	+	+	
<i>E. tomentosus</i> . . . . .	+	+		
<i>E. confervoides</i> . . . . .	+	+	+	
<i>E. siliculosus</i> . . . . .	+	+	+	
<i>E. penicillatus</i> . . . . .	+	+		
<i>E. fasciculatus</i> . . . . .	+	+		
<i>E. Hinksiae</i> . . . . .	+			
<i>Leptanema fasciculatum</i> v. <i>subcylindrica</i> . .	+	+	+	
<i>Elachista fucicola</i> . . . . .	±	±	±	±
<i>Sphacelaria britannica</i> . . . . .	±	—	—	
<i>S. radicans</i> . . . . .	—	±		+
<i>S. olivacea</i> . . . . .	—	—		
<i>Chætopteris plumosa</i> . . . . .	—	—	—	+
<i>Omphalophyllum ulvaceum</i> . . . . .		+		
<i>Punctaria plantaginea</i> . . . . .	±	—	+	
<i>Litosiphon filiformis</i> . . . . .	+	+	±	
<i>Isthmoplea sphaerophora</i> . . . . .	±	+		
<i>Stictyosiphon tortilis</i> . . . . .	—	±		
<i>Phæostroma pustulosum</i> . . . . .	+	+		
<i>Scytosiphon Lomentaria</i> . . . . .	+	+	+	
<i>Phyllitis zosterifolia</i> . . . . .	+	±	—	
<i>P. fascia</i> . . . . .	±	±	±	
<i>Coilodesme bulligera</i> . . . . .	+	+		
<i>Dictyosiphon Ekmani</i> . . . . .		+		
<i>D. Mesogloia</i> . . . . .		+	+	
<i>D. Chordaria</i> . . . . .		+		
<i>D. corymbosus</i> . . . . .		+		
<i>D. hippuroides</i> . . . . .		+	+	
<i>D. foeniculaceus</i> . . . . .	—	±		
<i>Desmarestia viridis</i> . . . . .	—	—	—	
<i>D. aculeata</i> . . . . .	—	—	+	—
<i>D. ligulata</i> . . . . .		—		
<i>Castagnea virescens</i> . . . . .		+	+	
<i>Leathesia difformis</i> . . . . .		+	±	
<i>Chordaria flagelliformis</i> . . . . .	—	±	+	+
<i>Chorda tomentosa</i> . . . . .		+		
<i>C. Filum</i> . . . . .	—	±	+	
<i>Saccorrhiza dermatodea</i> . . . . .	—	±	±	+
<i>Laminaria saccharina</i> . . . . .	±	±	—	+
<i>L. færdøensis</i> . . . . .		+		—
<i>L. nigripes</i> . . . . .		—		
<i>L. digitata</i> . . . . .	±	±	±	—
<i>L. hyperborea</i> . . . . .	+	—	—	—

## The Fruiting-period of the Species (continued).

	Spring	Summer	Autumn	Winter
<i>Alaria Pylaii</i> .....	—	+	+	
<i>A. esculenta</i> .....	—	+	+	—
<i>Fucus spiralis</i> .....	+	+	+	—
<i>F. inflatus</i> .....	+	±	—	—
<i>F. serratus</i> .....	+		+	
<i>F. vesiculosus</i> .....	+	±	±	±
<i>Pelvetia canaliculata</i> .....	+	+	+	±
<i>Ascophyllum nodosum</i> .....	+	+	±	—
<b>Chlorophyceæ.</b>				
<i>Chlorochytrium Cohnii</i> .....		+		
<i>C. inclusum</i> .....		+	—	—
<i>C. dermatocolax</i> .....	—	—	—	
<i>C. Schmitzii</i> .....		—		
<i>Codiolum Petrocelidis</i> .....	—	—	—	—
<i>C. gregarium</i> .....		—		
<i>C. pusillum</i> .....			+	
<i>Percursaria percursea</i> .....		+		
<i>Enteromorpha aureola</i> .....		+		
<i>E. Linza</i> .....	—	—	+	
<i>E. intestinalis</i> .....	+	+	+	—
<i>E. clathrata</i> .....		±	—	
<i>Monostroma groenlandicum</i> .....	—	+		
<i>M. Grevillei</i> .....	+	+		
<i>M. undulatum</i> .....	+	+		
<i>M. fuscum</i> .....	+	+	+	±
<i>Ulva lactuca</i> .....	+	+	—	
<i>Prasiola polyrrhiza</i> .....	—			
<i>P. furfuracea</i> .....		—		
<i>P. stipitata</i> .....	—	—	—	—
<i>Ulothrix consociata</i> var. <i>islandica</i> .....	—	+		
<i>U. subflaccida</i> .....		+	—	
<i>U. pseudoflacca</i> .....	+	+		
<i>U. flacca</i> .....	+	+		
<i>Pseudendoclonium submarinum</i> .....		—		
<i>Entoderma Wittrockii</i> .....	+	—	—	
<i>Acrochæte parasitica</i> .....	—			
<i>A. repens</i> .....		+		
<i>Bolbocoleon piliferum</i> .....		+	+	
<i>Ulvella fucicola</i> .....	—	—	—	
<i>Pringsheimia scutata</i> .....	—	+		
<i>Ochlochæte ferox</i> .....			+	
<i>Urospora mirabilis</i> .....	+	+	+	
<i>U. Hartzii</i> .....	+	+		
<i>U. Wormskioldii</i> .....	+	+		

## The Fruiting-period of the Species (continued).

	Spring	Summer	Autumn	Winter
<i>Chaetomorpha tortuosa</i> .....	—	—	—	
<i>C. Melagonium</i> .....	+	+	—	
<i>Rhizoclonium riparium</i> .....	—	+	—	—
<i>Spongomorpha vernalis</i> .....		+	+	
<i>Acrosiphonia albescens</i> .....	+	+	+	
<i>A. incurva</i> .....	+	+	+	
<i>A. hystrix</i> .....	+	+		
<i>A. flabelliformis</i> .....	—			
<i>A. penicilliformis</i> .....		+		
<i>Cladophora rupestris</i> .....	+	—	+	—
<i>C. hirta</i> .....	—		+	
<i>C. sericea</i> .....	+	+	+	—
<i>C. glaucescens</i> .....		—		
<i>C. gracilis</i> .....		—	—	
<i>Gomontia polyrrhiza</i> .....	+	+	+	
<i>Ostreobium Queketti</i> .....	—	—	—	
<b>Cyanophyceæ.</b>				
<i>Pleurocapsa amethystea</i> .....	—	—	—	—
<i>Plectonema norvegicum</i> .....			—	
<i>Phormidium autumnale</i> .....		—		
<i>Spirulina subsalsa</i> ..		—	—	
<i>Calothrix scopulorum</i> .....		—	—	
<i>Rivularia atra</i> .....			—	

By looking through the above table it is seen that in the case of a number of species the fructification-period is of long extent. Some nine species have been found fruiting all the year round, but I presume that by future investigations it will be proved that many more species bear fruit during the whole year. Kjellman (36) mentions 11 species which bear fruit all the year round in the Arctic Sea, and Rosenvinge (63) mentions 6 species which fruit all the year round along the coast of Greenland, and he adds that probably there are many more.

If we consult the table as to which season of the year is richest in fruit-bearing species it is easily seen that summer stands highest, with 64 % of the total number of species; then comes spring with 42 %, and after that autumn with 33 %. As the conditions during winter are so very little known no percentages can be given for that season.

It is well-known (Kjellman, Rosenvinge, Börgesen) that

in the case of many species both the vegetative period and the period of fructification is longer in the Arctic Sea and the northern part of the Atlantic Ocean than in the remaining more southern part of the boreal area of the same Ocean. It holds good also for Iceland, that both these periods are prolonged. Iceland, the Færøes and Greenland agree also in the fact that the summer is richest in fruit-bearing species.

### 3. Littoral Winter-vegetation at Reykjavík.

The littoral vegetation changes its appearance according to the season, and this is especially owing to the annual species. The vegetation is most luxuriant, and richest in species during spring and early summer; in the latter part of the summer the annual species decrease in number and a quantity of them disappear, and in the autumn only a small number of them is left. During winter only a few short-lived species are found, and some of them play either no part, or only an unimportant one in the vegetation which by that time is usually composed of perennial species. Thus, the number of the species of the winter-vegetation is much less than of the summer-vegetation because the *Chlorophyceæ*, which is the group in the littoral zone that is richest in species during summer, are few in number during winter; also the number of species of the *Phæophyceæ* is greatly reduced in the littoral zone during winter. It is the *Fucaceæ* which form by far the greater part of the mass of plants in the littoral zone, during the winter as in the other seasons of the year.

In December and January, in the winter 1911—1912, the vegetation of the upper and lower littoral zones was composed as follows: —

Highest of all a *Prasioletum stipitatæ* occurred in patches. *Prasiola stipitata* grew luxuriantly and had a normal appearance. It was not injured by the winter climate.

Below that came a well-developed *Porphyretum umbilicalis*, occurring also in patches on account of the surface-form of the coast. The *Porphyra* was both sterile and in fruit and had an entirely normal appearance.

Below that again came the *Fucaceæ*-community which, as is usually the case there, consisted at the top of a *Pelvetia-Fucus spiralis*-belt and at the bottom of the usual *Fucus*-belt (*Fucus vesi-*

*culosus*, *Ascophyllum nodosum* and *Fucus inflatus*). The vegetation was as luxuriant during winter as in the other seasons of the year when, however, the epiphyte-vegetation of the *Fucus*-belt is excepted. For further information concerning the *Fucaceae* see p. 173. Epiphytes, for instance such as *Pylaiella littoralis* and *Elachista fucicola*, which at the other seasons of the year are common everywhere in the *Fucus*-belt, were not observed. On the other hand, *Polysiphonia fastigiata* occurred in abundance on *Ascophyllum*. Of intermixed species in the *Fucus*-belt *Cladophora rupestris* may specially be mentioned; it occurred abundantly as well-developed specimens with the uppermost apex of the shoots destroyed.

A Hildenbrandietum occurred everywhere in the littoral zone, of similar appearance and extent as at the other seasons of the year.

In rock-crevices at the level of the *Fucus*-belt a well-developed *Rhodochortonetum Rothii* was found. The *Rhodochorton* was sterile and *Pleurocapsa amethystea* was growing upon it. In such crevices were noted in addition: — *Pylaiella littoralis*, sterile and in very small quantity; *Acrosiphonia* sp., a few filaments; *Cladophora rupestris*, abundant; *Polysiphonia urceolata*, sterile and without hairs and sparse, and *Callithamnion* sp.

The vegetation of the Pools was on the whole very poorly developed. The upper pools, at the level of *Pelvetia* and *Fucus spiralis*, contained a few small individuals of *Cladophora sericea* f., a few filaments of *Pylaiella littoralis*, a few small individuals of *Monostroma fuscum*, and Diatoms in abundance. In such pools *Cladophora sericea* forms a dense and luxuriant vegetation in spring and summer. *Fucus inflatus* f. *linearis* grows also in these pools in spring and summer, but was not found there in winter. It appears as if this form is annual, at any rate in the upper pools. The lower pools, almost at the level of the lower part of the *Fucus*-belt, contained only a poor vegetation. *Monostroma fuscum*, however, occurred fairly abundantly, but *Halosaccion ramentaceum* was found more sparsely; on *Halosaccion* was growing *Elachista fucicola* v. *lubrica* with unilocular sporangia and somewhat sparse assimilatory filaments, and also *Ceramium* sp.

Below the *Fucus*-belt, in the lower littoral zone (upper part of the semilittoral belt) were found at Elferseyjargrandi, *Rhodymenia* distributed in patches here and there, many of them of rather considerable size. The majority of the individuals were old,



with abundance of new shoots. The *Rhodymenia*-vegetation is never really luxuriant in this place; it attains, however, to a greater luxuriance in spring and summer than during winter. *Halosaccioneta* occurred also here and there, but sparsely and not nearly as abundantly as in spring and summer, but the same applies to it, as to *Rhodymenia*, that it never grows really luxuriantly in this place. There were noted in addition: — *Monostroma fuscum*, *Pyraliella littoralis* (extremely sparsely) and *Enteromorpha intestinalis* f. *prolifera*, also extremely sparsely. *Lithodermeta* occurred abundantly and were well-developed, but the species was sterile. A *Sphacelarietum* composed of *Sphacelaria radicans* was found here and there. The plants were low in growth, sterile and without hairs. A *Gigartinetum* occurred here and there of about the usual extent.

Just below the limit of low-tide I gathered the uppermost stragglers from the sublittoral zone. There *Laminaria saccharina*, *L. digitata*, *L. hyperborea* and *Alaria esculenta* f., were growing. All the *Laminarias* were sterile and the new laminæ had not begun to grow. The frond of the *Alaria* was usually torn in pieces; in the middle of the stipe there were old sporophylls. The uppermost part of the stipe, just below the leaf-base, was young and evidently growing. Lowermost in the part that was growing, small projections could be seen on the two sides, which were evidently the beginnings of new sporophylls.

The following species were found thrown ashore: — *Laminaria saccharina*, *L. digitata*, *L. hyperborea*, *Alaria esculenta* f., *Saccorrhiza dermatodea*, *Desmarestia aculeata*, *Odonthalia dentata*, *Petrocelis Hennedyi* richly fruiting (on *L. hyperborea*), *Rhodochorton Rothii* (on *L. hyperborea*), *Delesseria sanguinea* with the small tetraspore-bearing fronds, and *Ptilota plumosa* with tetraspores.

For the further understanding of the winter-life of the algæ it may be mentioned that the winter of 1911—1912 was unusually mild at Reykjavík.

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## ERRATA.

P. 3, line 6, for of read off.

P. 29, line 15, for Kylin (43) read Kylin (45).

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# THE BOTANY OF ICELAND

EDITED

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## PART I

2. AN ACCOUNT OF THE PHYSICAL GEOGRAPHY OF ICELAND  
WITH SPECIAL REFERENCE TO THE PLANT LIFE

BY

TH. THORODDSEN  
PROFESSOR, PH. D.

(PUBLISHED BY THE AID OF THE CARLSBERG FUND)

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2.

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WITH 36 FIGURES IN THE TEXT



## CONTENTS.

	Page
I. General Topography. Geology.....	191
Glaciers .....	200
Snow-line .....	202
Rivers .....	205
Lakes .....	209
Geology .....	211
Volcanoes and Lava-streams .....	219
II. Conditions pertaining to Surface and Soil ..	232
III. Climate.....	265
IV. Account of the General Distribution of Plant-life.....	292
V. A Sketch of the Chief Plant-formations of Iceland.....	317





## I. GENERAL TOPOGRAPHY. GEOLOGY.

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**I**CELAND is a large island in the North Atlantic. It stretches from  $63\frac{1}{2}^{\circ}$  to  $66\frac{1}{2}^{\circ}$  N. lat. and from  $13^{\circ}27'$  to  $24^{\circ}30'$  W. long. fr. Gr.; consequently, the Arctic Circle touches its northernmost points, and as a result, along the northern coast, the midnight sun turns night into day for a short time during summer. In the most northerly districts the sun is above the horizon for a week; at Reykjavík the longest day is 20 hours 56 minutes, the shortest 3 hours 58 minutes. The distances from Iceland to the neighbouring countries are as follows: — to Norway 950 km., to Scotland 900 km., to the Færöes 450 km., to the east coast of Greenland 330 km., and to Denmark 1500 km. The length of the island from east to west is 490 km., and the breadth from north to south is 312 km. Its area is about 104,000 sq. km.

Iceland is a very mountainous country although it has not any true mountain-chains; it is most properly described as a continuous table-land with an average height of 700—1000 metres above sea-level; besides, there are only narrow borders of coastal land, valleys which cut into the table-land from all sides, and a few small areas of level land towards the south and west. Scarcely one-fifteenth of the country can be reckoned as lowland. Owing to its northern situation, its height above sea-level, and the resulting severe climate, only a relatively small part of the country is inhabitable. More than two-thirds of the entire area of the country is situated at so great a height above sea-level that almost no vegetation can thrive there. The sandy and stony deserts of the interior plateau, the lava tracts, and the glaciers are not fit dwelling places for human beings; therefore it is almost exclusively the coasts and the valleys which are inhabited.

The coast of Iceland is upon three of its sides indented by fjords and bays, while the south coast is almost wanting in indentations — fjords, harbours, etc.; the coast-line is best developed towards the north-west, where a peninsula with many fjords projects from the main land. The coast-line of Iceland is about 6000 km. in length, of which one-third belongs to the north-western peninsula. The indentations of the coast may be divided, according to their origin and size, into two groups, the large bays which are probably formed by the sinking of the earth's crust, and the fjords proper which appear to owe their origin chiefly to erosion. Along the south coast the great Jökulls (snowfields) descend toward the sea and the masses of gravel carried down from the glaciers have, in the course of time, filled up all the fjords, causing the sea outside the fjords to be so shallow that it is dangerous for vessels to approach the coast. The breakers throw up bars of coarse shingle which dam the waters of the numerous glacier-rivers, and so shoals and shifting lagoons are common along this coast; the largest of them are to be found towards the south-east (Alftafjörður, Papos and Hornafjörður). In the western part of the south coast the fjords and bays of olden times have been filled up not only with the sediments of glacier-rivers, but also with great lava-streams. From the west two large bays, Faxafjörður and Breiðfjörður, extend inwards, they are separated by the mountainous and volcanic Snæfellsnes. The former of these bays is 68 km. in length and 90 km. in breadth, the latter 124 km. in length and 74 km. in breadth; from them several small fjords extend inwards, especially from Breiðfjörður, which at its head divides into two large arms, Gilsfjörður and Hvammsfjörður. The north-western peninsula (Vestfirðir), as mentioned above, is indented by numerous fjords, and there are several excellent harbours, trading-stations and fishing villages in those fjords which turn their mouths towards the north-west; of these fjords the largest are Arnarfjörður and Isafjardardjup, both of which have many branch-fjords. On the north coast there are also many large indentations which are separated by mountainous peninsulas; of these bays and fjords the following are the largest, proceeding from west to east: Húnaflói, Skagafjörður, Eyjafjörður, Skjálfandi, Axarfjörður and Thistilfjörður; and from these larger bays several smaller fjords extend further into the country. Of the peninsulas the following may be mentioned: Skagi, Tjörnes, Melrakkasljetta and Langanes; the two large peninsulas on either side of Eyjafjörður have no distinctive

names. In East Iceland there are also many larger and smaller bays and fjords; the largest and best-known are Vopnafjörður, Hjeradsflói, Seyðisfjörður, Reyðarfjörður and Berufjörður. Although the coast of Iceland is so cut up by fjords, it is not especially rich in islands; only in Breiðifjörður is there a number of islands and islets, in two large groups or collections; otherwise, the islands along the coast of Iceland are few and scattered, and are usually high and rocky. To the SSW. of Iceland are situated the volcanic islands, the Vestmannaeyjar and Fuglasker, and north of Iceland, in the Arctic Ocean, the Isle of Grímsey, 45 km. from the coast.

The north, east and north-west coasts of Iceland, which abound in fjords, are everywhere rocky, and rise steeply from the sea like black walls 300—500 metres in height, composed of from 30 to 100 layers of basalt, distinguishable as narrow ledges or steps. Numerous small streams have excavated channels in the rock-sides, and leap in small cascades from ledge to ledge. The foot of the mountain and the narrow coastal-land are usually green and grassy in places where the rocks are not too steep, but the mountain itself is chiefly of dark rocks, covered with gravel, and with white patches of snow in the higher regions. At the head of the fjords, whence the various valleys branch off into the interior of the country, there usually occur several or a few groups of mountains with crests, ridges and peaks often of the most fantastic form, while the edge of the mountains along the fjords resembles walls with bastions and battlements. At many of the fjords there are trading-stations with the wooden houses painted white or red, while scattered under the sides of the mountains the white gables of the farm-houses peep forth amidst the sap-green home-fields. On the south coast the mountains retreat and the strand is bounded by sandy and pebbly flats; along these tracts the mountains are usually more rounded and softer in outline, as they are composed of tuff and breccia. The highest parts of the plateau are covered by snow-fields (Vatnajökull, Myrdalsjökull) from which large and small glaciers come down through every cleft, and extend to the level country.

Iceland consists of two distinct table-lands, one large (about 88000 square km.) and one much smaller (about 9000 square km.), the north-western peninsula, which is attached to the mainland by a narrow neck of land only, forming a table-land by itself. The large table-land which almost entirely occupies the remaining part of the island is highest towards the SE. where the snow-masses of

Vatnajökull cover an area of about 8000 square km. The axis of elevation lies from NW. to SE., from somewhere near the head of Hvammsfjörður to Hornafjörður; it does not, however, consist of one continuous ridge, but of a series of snow-covered, dome-shaped mountains separated by broad stretches of more level ground. These snow- and ice-covered domes are strictly speaking a series of small plateaus which rise from the main plateau to an absolute height of 1400--2000 metres, as compared with 600—1000 metres above the plateau. The most easterly of the great glacier-bearing mountains is Vatnajökull which is separated from the much smaller Tungnafellsjökull (100 square km.) by Vonarskarð (1000 metres); between Tungnafellsjökull and Hofsjökull (1350 square km.) lies the broad stretch of level ground, Sprengisandur (650 metres); west of Hofsjökull and between the latter and Langjökull (1300 square km.) lies Kjölur or Kjalvegur (600 metres); and between Langjökull and Eiríksjökull (100 square km.), Flosaskarð (800 metres). The plateau north of the last-mentioned ice-mountains abound in lakes and bogs. The interior plateau consists chiefly of deserts almost destitute of vegetation, but the surface varies somewhat in character in accordance with the geological nature of the underlying rock. Where basalt or dolerite forms the substratum, the surface is strewn with innumerable angular blocks of rock, split asunder by the action of frost; where tuff and breccia form the foundation, the surface is usually covered with gravel and fragments of slaggy lava which have been loosened from the breccia by the action of weathering. More than one-half of the plateau is overlain by more recent formations — lava, blown sand, volcanic ashes, glacial formations, clay and river-gravel. The lava-fields, taken together, cover a very large area in the interior and present a most desolate scene; as far as the eye can reach only a black, hardened mass is seen, and the dark colours are only here and there interrupted by mounds of reddish slag, smoking craters, scattered snow-drifts, and in the distance by glistening, white Jökull-domes; there is no sign of life and an oppressive silence reigns over the land.

The interior plateau is trenched by many valleys, chiefly towards the north and east; between these valleys long mountain spurs — the skeletal ribs of the eroded plateau — branch outwards toward the sea. Of these, the mountain-mass which extends towards the south, and is crowned at the top by Myrdalsjökull, is the most considerable. Towards the west the two volcanic mountain-chains



extend outward upon Reykjanes and Snæfellsnes. The mountain-chain on Reykjanes is broad and flat at the top; it is divided into several smaller plateaus (300—600 metres) with rows of craters and volcanic mountain-tops, and it sinks down more and more towards the west so that the extreme end of the peninsula consists chiefly of low-lying lava-fields with a few low, isolated mountain-tops. The mountain-chain which extends toward Snæfellsnes is higher (600—900 metres), but much narrower: it is also very vol-



Fig. 1. Snæfellsjökull (West Iceland).

canic and terminates in the ancient, ice-capped volcano, Snæfellsjökull (1446 metres).

In North Iceland several great mountain-masses proceed from the high land outward upon the peninsulas, and from the head of the fjords long valleys extend into the country; by the extensive branching of the valleys, the mountains are divided into a number of ridges and peaks, which however when examined more closely, prove to have been cut out of an originally continuous plateau. Several valleys lead up from Húnaflói, of which the western are narrow, but the eastern (Víðidalur, Vatnsdalur, Blöndudalur) are broader and more fertile; these latter open out toward the low land (Thing) at the head of Húnaflói. The large peninsula between Skagafjörður and Eyjafjörður is occupied by mighty, steep mountain-masses which are intersected on both sides by numerous valleys, the largest (Öxnadalur, Hörgárdalur, Svarfaðardalur) being on the

east. On this peninsula occur the greatest heights in northern Iceland (Vindheimajökull, 1445 metres; Kerling 1350 metres; Rimar, 1261 metres). Broad, fertile and thickly-inhabited main valleys stretch up from the head of Skagafjörður and Eyjafjörður; east of Eyjafjörður, between the latter and Skjalfandi, the stern, wild mountains rise to a height of 1200 metres, and there Fnjóskadalur, which cuts through these mountains towards Eyjafjörður from the east, opens out. These mountains fall abruptly towards the east down towards Bárðardalur (70 km. long), but east of that valley the country becomes lower, and has a different geological structure and character; hitherto, basalt has been the dominant rock, but hereafter, for a long distance, the substratum is formed of tuff, breccia and recent volcanic formations. East of Bárðardalur the plateau gradually sinks down towards the sea, and inhabited spots occur, not only along the coast and in the valleys, but also here and there upon the high land itself (Myvatnssveit, 300 metres above the level of the sea; Fjallasveit, 450—500 metres). Upon these areas of the plateau there are many isolated mountains and mountain-ridges, volcanoes and lava-streams.

The eastern part of Iceland is called collectively Austfirðir. There the country is very mountainous towards the coast and indented by deep fjords which are bounded by high, precipitous rock-walls, basalt being now again the dominant rock. From Hjeraðsflói two long valleys, 80—90 km. in length, extend towards the south. These valleys, which unite lower down, are called Jökuldalur and Fljótsdalshjerað; the latter lies behind the fjord district of eastern Iceland and cuts it off from the interior plateau which is here somewhat lower than the coastal mountains, which reach a height of 10—1100 metres and even more. Towards the south there are two smaller Jökulls, Thrandarjökull and Hofsjökull í Lóni, with an area of 100 and of 80 square km. and a height of 1100—1200 metres respectively. Near Hornafjörður the character of the coastal land changes completely, because there the plateau, to its extreme edge, is buried beneath the snow and ice-fields of Vatnajökull. The low, narrow and sandy coastal border is irrigated by glacier-water streaming down from the numerous glaciers which advance through every cleft and valley. Here and there, along the edge of the snow-field, mountains and rocky promontories appear, and of the former the imposing volcano of Örafajökull (2119 metres), Iceland's highest mountain, is the most noticeable; other promontories and mountains near the southern edge of Vatnajökull have a height of 1100—1500 metres.

North of the mountain of Lómagnupur (770 metres), which is a breccia-promontory rising steeply from a sandy flat, the glaciers recede from the coast and the plateau is continued as a low hilly edge as far as Mýrdalsjökull, the snow-masses of which cover the upper part of the above-mentioned southern spur of high land and which has an area of about 1000 square km., reaching a height of 1666 metres in the volcano of Eyjafjallajökull. Another very active and dangerous volcano, Katla, also hides itself beneath the glaciers of Mýrdalsjökull. West of this snow-field the plateau retires again from the coast; the deep valley of Markarfljót separates Mýrdalsjökull from Tindfjallajökull (1462 metres), and north of the latter lies the oblong, volcanic Torfajökull (1400 metres) and the famous volcano Hekla (1447 metres). North-west of Hekla and near Geysir, the plateau retires to its greatest distance from the coast (about 80 km.), but bends thence again towards the south-west, outwards towards the peninsula of Reykjanes.

The lowlands of Iceland cover only a small area; in the north and east there is no low land with the exception of the larger valley-mouths, e. g. at the head of Húnaflói, Skjálfandi and Fljótsdals-hjerað and the extreme end of the peninsulas of Skagi and Mel-rakkasljetta. Larger lowland areas occur only in South and West Iceland; they are however small in extent compared with the mountainous country and the table-lands. Although the lowlands only comprise one-fifteenth of the entire area of the country, yet together with the valleys they are of very great importance because tolerably favourable climatic conditions and a closer vegetation, permitting fixed habitations and the rearing of cattle, are found almost exclusively there; the inhabitants of the few dwellings which occur scattered in the lower parts of the plateau must struggle with severe conditions and are almost entirely reduced to sheep-rearing alone. But by no means all the lowlands are grass-covered; large tracts of lava, glacier-gravel and blown sand are extremely poor in plant-life. On the south coast the country nearest to the sea is quite flat, from Hornafjörður to Reykjanes, but in many places this level land is so narrow that it consists only of an insignificant coastal border; in other places it widens out into larger plains and extends further into the country. Between Hornafjörður and Mýrdalsjökull, below Vatnajökull, the coastal country is formed by deposits from the numerous glacier-rivers and consists exclusively of sand and gravel; the lowland here is often flooded by branching torrential glacier-

rivers, so that no vegetation can thrive here. Below the southern edge of Vatnajökull the farmsteads are therefore confined to oases separated from one another by gravel-deserts and swollen glacier-rivers. In many places the people have been obliged to move their houses up on the mountain sides in order to avoid inundations caused by the glacier-waters, and here the mountain-sides facing south are covered with a luxuriant plant-growth, while the level country below is devoid of vegetation. The sandy tracts have different names, such as Breiðamerkursandur, Skeiðarársandur, Brunasandur, Mýrdalssandur, Sólheimasandur, etc. Of these the largest is Skeiðarársandur (about 900 square km.), and taken together they cover an area of about 2700 square km. Between Lómagnupur and Mýrdalsjökull the lowland becomes broader and is covered by extensive lava-fields, blown sand, gravel and volcanic ashes, as large volcanoes occur in the neighbourhood. The largest area of low land in Iceland lies between Eyjafjallajökull and the peninsula of Reykjanes and is about 4000 square km. in extent; it is hemmed in by tuff-mountains which in many places fall abruptly towards the plain. The lowest part of the lowland is only slightly raised above sea-level, but it rises gradually towards the interior where it ultimately branches off into different valleys; near Geysir it reaches its greatest height above sea-level, about 150 metres. The low land is not flat everywhere, some parts of it are hilly, and a few isolated mountains also rise from the plain. West of Hekla the lowland, by means of a gentle rise, is in direct connection with the interior plateau, to the great danger of the inhabited districts, as the blown sand, volcanic ashes and pumice dust which cover large areas of the interior have thereby free access to the lowlands; therefore, in these regions, during north-westerly storms, large tracts of grass-covered and inhabited land have been overwhelmed in the course of time. The lowlands consist chiefly of grassland, and nowhere in Iceland do farmsteads occur so closely together as here, these districts being well-suited to cattle-rearing. Three very well-supplied rivers run through the lowland, viz. Markarfljót with a large delta-land (Landeyjar), Thjórsá and Ölfusá, and besides these there are many smaller ones. The eastern part east of Thjórsá is called Rangárvallasýsla, the western Árnessýsla. At the head of Faxaflói there is another low area (about 1000 square km.) which on an average has a height of only 20—30 metres. It is bounded by steep, basalt mountains which are arranged in a semicircle around



the lowland which is very swampy and above which project numerous low, isolated, basalt hills. The eastern part is called Borgarfjörður and the western Mýrar. From the low land several wide valleys extend inwards between the mountains.

The north-western peninsula, as mentioned above, constitutes a small plateau by itself and is separated from the mainland by Breiðfjörður and Húnaflói; the isthmus which connects the peninsula with the mainland has a breadth of only 7 km., and rises to a height of 228 metres. The coast of north-west Iceland, which is much indented by fjords, is bounded everywhere by steep, dark mountain-sides which often rise abruptly, even vertically, from the sea to a height of 400—500 metres. The mountains are everywhere composed of horizontal, or slightly inclined, basalt-layers which are highly denuded by erosion, so that numerous small valleys, cirques, clefts, ridges and bastions occur as in other basalt regions of Iceland. By climbing the mountain-edge up in the highlands, and ascending to a sufficient height it will be seen that fjords and valleys have trenced the plateau with great regularity. The eye wanders freely over wide wastes, the valleys and fjords either disappear or are seen as insignificant clefts, and a monotonous table-land lies stretched out to view, the surface of which is broken only by low ranges of hills, and ice-striated basalt-masses with large stretches covered by angular blocks of rock and scattered snow-wreaths. It is often extremely difficult to traverse this kind of ground, across an ocean of rocky blocks, where the clay and the gravel between the blocks often occur as a slushy mass owing to the thawing of the numerous patches of snow. Only now and then can a solitary, stunted Alpine plant be seen maintaining a miserable existence in the shelter of the large blocks of rock. The plateau of the north-western peninsula has an average height of only about 600 metres, and where it is highest (800—900 metres) the snow drifts and consolidates into *névé*-domes — Gláma (about 60 square km.) towards the SW. and Drangajökull (about 350 square km.) towards the NE. The numerous valleys which lead up from the fjords and cut into this plateau are similar in character to the other Icelandic valleys in the basalt districts, so it will be convenient to describe their physiographical characters collectively. The bottom of the valley rises gradually in broad rock-terraces, upon the surface of which bogs and small lakes often occur, and it terminates amphitheatrically in a large cirque, down the steep rocky sides of which several streams fall in cascades.



The mouths of the contributory valleys are often situated at a higher level than the bottom of the main valley and along the mountain-sides a series of cirques are often found. Hundreds of streams carry gravel and rock-fragments down to the foot of the mountain and to the valley, and below each notch in the mountain there is, therefore, a flat cone of gravel which extends down the side of the mountain to the bottom of the valley; each little cirque and each notch has, like an hour-glass, according to the law of gravitation, emptied its contents upon the level land below. The foot of the mountain is covered with plants, but any aggregate of vegetation has rarely been able to extend higher than half-way up the mountain-side; only on ridges between clefts and hollows, where neither floods, rock-slips nor avalanches can do harm can the plant-covering extend upwards in longer tongues, while the upper half of the mountain-side consists but rarely of anything except bare rock-ledges or rock-faces or heaps of stones. On a closer investigation, a few individual plants will however be found seeking cover, shelter and foothold among the blocks of rock and in the crevices. In places where springs are trickling out in a row from between rock-strata there is often a luxuriant vegetation of yellowish-green mosses which form soil and pave the way for the higher plants. Even on the most precipitous valley-sides, sheep are seen scattered about seeking the mountain-plants which peep forth between the stones. Upon the north-western peninsula there are no lowlands, but only a narrow border of coastal land which is due to the action of the breakers at a time when the sea-level was higher than at present. Only the narrow coastal land along the sides of the fjords is inhabited, and the inhabitants are chiefly dependent upon the sea for subsistence. Where the land which fringes the coast becomes somewhat broader and the valleys more grassy, as along the north coast of Breiðfjörður, the inhabitants' chief means of sustenance is sheep-rearing; where the fjords are small, the mountains steep, and the coastal land has disappeared, as along the coast south of Cape Nord, the inhabitants maintain themselves almost entirely by the catching of birds upon the steep sea-cliffs.

**Glaciers.** The snow- and ice-covered mountains (Jökulls)<sup>1</sup> of Iceland, taken together, cover an area of 12700 square km. and

<sup>1</sup> In Iceland, by "Jökull" a glacier-bearing mountain is usually meant, but sometimes the term is used for the masses of snow and *névé* upon the mountain.

through their glaciers and glacier-rivers they exert a great influence upon the surface and climate of the country and upon the conditions of life of the inhabitants. The Icelandic climate is specially adapted to the development of large glaciers, for the air is raw and cold and moist, the amount of rainfall considerable and the summer-heat slight. The amount of precipitation is greatest towards the south-east and there the interior table-land is covered by the great Vatnajökull. The altitude of the snow-line varies from 400 to 1400 metres in the different parts of the country, and the level above the sea at which the glaciers end differs greatly: in the north on the north-western peninsula, and in the south near Vatnajökull, the glaciers descend almost to the sea, to 25 metres and 9 metres above sea-level respectively at the lowest points to which they descend. The great ice-mountains of Iceland are without exception closely associated with the plateau. Large areas of the highest part of the plateau are covered with *névé* which occurs as slightly-arching domes or undulating snow-fields of great thickness. Prominent mountain-peaks are rare; the latter do not appear until near the edges of the snow-fields and usually as outstanding summits of the underlying rock. The surface of these snow-fields is devoid of gravel; this does not appear until it does so at the extremities of the glaciers which are often quite black with it and with sand and blocks of rock. The large glaciers which descend from these *névé*-covered flats have, on an average, a very slight declivity; only in places where precipitous mountain-peaks project from the edge of the snow-field, do steep glaciers of small dimensions occur. The large glaciers of Iceland closely resemble the glaciers typical of Arctic countries; but there are a great many small glaciers which resemble those of the Alps. Several of the broad glaciers which descend from Vatnajökull cover a very considerable area (e. g. Dyngjujökull 400 square km., Bruarjökull 500 square km., etc.). Peculiar to Iceland are the so-called "glacier-torrents" (*Jökul-hlaup*). When the glaciers, by the eruption of volcanoes hidden under the ice, are broken to pieces and melt, the large stretches of land beneath them are inundated by a roaring sea of dirty water with swirling icebergs. Such catastrophes may cause great changes in the surface-features of the surrounding country, as the waterfloods often carry along with them an incredible quantity of gravel and rocky blocks. In this way the volcano of Katla especially has caused considerable changes — the course of rivers are constantly changed, the smaller

fjords have been filled up even within historic times, and several large parishes and districts have been destroyed. Örafajökull has, in the same manner, caused considerable destruction; while the waterfloods of Skeiðarárjökull, which were especially frequent during the 19th century, have done less material damage, as only uninhabited sandy wastes were inundated. Minor glacier-bursts are also occasionally due to lakes and rivers, which have been dammed by glaciers, suddenly breaking through their barriers and inundating the district. These glacier-bursts have a great effect upon the plant-life, because no permanent vegetation can exist upon gravelly and sandy flats which are constantly inundated by waterfloods carrying large pieces of ice; therefore very large stretches of lowland in the neighbourhood of such volcanoes and glaciers are destitute of plant-growth, for what little vegetation appears in the period between the glacier-bursts is quickly destroyed. The general physiographical conditions pertaining to the glaciers of Iceland may be best seen by a study of the table opposite.<sup>1</sup>

**Snow-line.** In Iceland it is not easy to determine the snow-line, owing to the great variability of the climatic factors. Because of the great annual and periodical variability of temperature and of the circumstances connected with precipitation, the snow-line also varies. In Iceland three kinds of height-levels connected with the vertical distribution of the snow, and dependent on climatological and orographical conditions, may be supposed to exist. The snow-line proper, which signifies the lowest limit of the permanent, continuous snow-covering of the mountains, is not subject to very great changes from year to year. Below this comes a zone of detached, more or less closely placed, patches of *névé* and wreaths of snow; these never melt entirely, but either are added to or else diminish according to the character of the year. Below this zone comes the most variable of the snow-coverings: scattered snow-drifts which to a greater extent than the others are dependent on orographical conditions. These snow-drifts may persist through a series of damp and cold years, but dwindle almost to nothing or disappear entirely in warm and dry years. The snow at Drangajökull upon the north-western peninsula may serve as an example. Here, on

<sup>1</sup> Here it should be noticed that many of the figures for the area of the Jökulls are approximate and given as a rough estimate, because the maps of a great part of Iceland, and especially of the plateau are still very imperfect.

Names of Jökulls	Approximate area in sq. km.	Greatest height above sea-level in metres	Altitude of snow-line in metres	Number of glaciers known	Altitude of inferior end of glacier in metres
Gláma.....	cir. 60	901	cir. 650	—	—
Drangajökull.....	350	890	—	7	—
— east side.....	—	—	400	—	30
— west side.....	—	—	650	—	25
Snæfellsjökull.....	23	1446	—	2	560
— north-east side .	—	—	650	—	—
— south-west side.	—	—	1000	—	—
Langjökull.....	1300	1400	—	31	—
— south-west side ..	—	—	900	—	600
— east side.....	—	—	1000	—	435
— north-west side !...	—	—	1000	—	628
— north side.....	—	—	1100	—	—
Eiríksjökull.....	100	1798	—	6	606
Ok.....	15	1198	900-1120	—	—
Hlöðufell.....	1	1188	960	—	—
Arnarfellsjökull (Hofsjökull) ..	1350	1700	—	19	—
— east side.....	—	—	—	—	552
— north side.....	—	—	1200	—	910
Mýrdalsjökull.....	1000	1666	—	20	—
— north side.....	—	—	1100	—	700
— south side.....	—	—	8-900	—	97
— east side.....	—	—	6-700	—	205
— west side.....	—	—	1000	—	220
Torfajökull.....	100	1200	950	—	—
Tindfjallajökull.....	22	1462	950-1000	5	570
Vatnajökull.....	8000	2119	—	41	—
— west side.....	—	—	1000	—	635
— south side.....	—	—	900	—	9
— north side.....	—	—	1300	—	600
— east side . . . . .	—	—	950	—	700
Hofsjökull í Lóni.....	80	1200	850-950	1	—
Throndarjökull.....	100	1200	900	—	—
Snæfell.....	15	1822	—	2	—
Tungnafellsjökull.....	70	1600	1300	2	—
Dyrfjöll.....	5	1131	600	—	—
Fönn.....	10	900	—	—	—
Kaldbakur.....	5	1161	—	—	—
Vindheimajökull.....	10	1466	—	1	—
Myrkárjökull.....	10	1200	—	1	—
Túnahryggsjökull..	40	1200	—	4	—
Unadalsjökull.....	20	1200	—	—	—
	12686	—	—	142	—

the eastern side the snow-line stands at a height of 400 metres above sea-level, on the western side at an altitude of 650 metres. Upon the plateau itself, around the base of Drangajökull, there are numerous large, scattered wreaths of snow which taken collectively would cover a large 'area; they occur at an altitude of 250—500 metres. In the summer of 1886—87 there occurred, in addition, numerous wreaths at a lower level — in sheltered places even close to the sea-shore, especially at Snæfjallaströnd, where very long snow-drifts were lying on the terraces of the basalt beds. In these districts old banks of snow are usually very frequent at a height of 50—100 metres above sea-level; the climate also is very raw and the precipitation considerable; there are occasional snow-storms in the middle of summer, and drift-ice with cold, damp fogs and drizzling rain is a frequent visitor. The sea cuts into the land from all sides.

Above the snow-line proper there is naturally no vegetation, with the exception of a few individuals which maintain their existence on projecting rocks and "Nunataks" in the ice. In the region of permanent snow-drifts there occurs, only here and there, a poor and very scattered rocky-flat vegetation, but in the zone of the variable snow-drifts there may often be a vegetation of different species which is rather luxuriant, considering all things. According to my measurements in the years 1882—1898 the snow-limits were about as follows (the snow-limits given in the table on p. 203 may serve for comparison): —

	Snow-limit in metres	Lowest limit of the permanent snow-drifts in metres	Lowest limit of the variable snow-drifts in metres
Northern part of the north-western peninsula . . . . .	400-650	250-500	50-100
Snæfellsnes . . . . .	800-1000	cir. 700	500-600
Ódáðahraun . . . . .	1400	1000	—
Mývatn . . . . .	—	700-800	—
Peninsula NE. of Eyjafjörður . . . . .	1000	450-500	200
Austfirðir . . . . .	900-1000	500-550	300-400
Plateau between Vatnajökull and Mýrdalsjökull . . . . .	1100	600-700	—
Arnarvatnsheiði NE. of Langjökull . . . . .	1000-1100	600-700	500-600
The neighbourhood of the southern lowland	1000-1100	800-900	—



**Rivers.** Iceland possesses numerous rivers of considerable size; their volume is due to the damp climate of the land and to the great number of glaciers. The Jökulls serve as huge water-reservoirs, from which the majority of the larger rivers are supplied, and the glacier-plateaus also attract rain and other atmospheric precipitation, so that the supply is always uniform. The volume of water is greatest in the lower-lying districts because the plateau above 500—600 metres, to a great extent, is covered with lava, gravel and loose sand which absorb all the moisture; but it reappears further down, and below the 500 metre line there are extensive bogs both in the lowest part of the plateau, in the lowlands and in the valleys. In the lava-deserts both on the plateau and in the lowlands, the rain and melted snow disappear immediately, and large tracts are quite destitute of water; but at the edge of the lava numerous springs bubble forth from the earth. The water which at first is usually turbid and intermingled with glacier-mud, becomes filtered by passing through the lava, and is therefore very pure and clear in the springs. When there is no outlet, water is sometimes found in the lava-field itself, at the bottom of deep clefts; as for instance, the renowned, cold, crystal-clear water in the lava-clefts near Thingvellir. In early summer, during sudden thaw, while the frost-layer still persists in the ground, extensive gravelly and clayey flats on the plateau and in the lowlands are turned into morasses, but when the ice of the subsoil melts later in the summer outlets are again opened for the surface-water so that the gravel-fields are drained. In the valleys numerous springs make their way through the basalt along the mountain-sides, often in long rows between the layers, and can be detected by the green mosses which grow luxuriantly around them.

Icelanders draw a distinction between “bergvatn” (mountain-water) which is clear, and “jökulvatn” (milky-white glacier-water) which may have a muddy, yellowish colour or a chocolate-brown colour according to the amount and kind of glacier-clay carried in it. The amount of clay in the glacier-water is larger in summer than in winter and, again, the glacier-rivers are clearer and of less volume in the morning than later in the day. Differences in the weather — cold or warm or wet or dry years — have the greatest influence as regards the volume of water in the glacier-rivers. In dry and warm summers the clear rivers are but small, while the water carried by the glacier-rivers increases to double or three times the usual volume. As the glacier-rivers are so dependent upon the

melting of the snow their size varies from day to day and from year to year; many glacier-streams which disappear entirely during winter, carry in warm summers an immense volume of water. Almost all Icelandic glaciers rest on soft rocks (tuff and breccia) upon which erosive action is very active; therefore, the Icelandic glacier-rivers carry down an immense amount of rock in the form of mud, sand, gravel and blocks of stone; for this reason they are hardly ever found entering fjords or deep bays, these having quickly become filled up in cases where they formerly so entered, while the Jökulls (glacier-bearing mountains) are surrounded by large sandy and gravelly tracts which for the most part owe their origin to the rivers.

Taking the whole of the island into account, rivers containing glacier-water are decidedly in the majority. South of Vatnajökull clear water is almost unknown, as all rivers and brooks originate in the glaciers. There all the rivers flow down to the coast by short courses in torrential current, and during summer some of them are so broad that it takes hours to cross them — but then it must be remembered that it is necessary, in the middle of the river, to go a long way round, on account of the current and depth. On the flat, sandy tracts the rivers are constantly changing their course, and greater and smaller changes take place daily. All glacier-rivers branch abundantly.

In accordance with the slope of the land, the longest and largest rivers flow in South Iceland towards the south-west and south, and in North Iceland towards the north; the majority of them rise on the plateau at a height of 600—900 metres above sea-level, a fact which should be correlated with the limits of the glaciers in the interior. Although the Icelandic rivers carry a comparatively great volume of water yet they are not navigable, because of their usually steep fall, their torrential current, and their tendency to spread out and subdivide into numerous branches in the low land. The largest rivers of Iceland are as follows: — From the south edge of Vatnajökull rise Jökulsá í Lóni, Hornafjarðarfljót, Jökulsá á Breiðamerkursandi, Skeiðará and Núpsvötn; the last three are considered to be the most dangerous glacier-rivers of Iceland. From the west edge of Vatnajökull rise Hverfisfljót, Skaftá and the well-supplied Kúðafliót; this last also receives a large supply of water from Mýrdalsjökull. From the latter another river flows down — the short, but torrential Jökulsá á Sólheimasandi, also called

Fúlilækur, which often has minor "glacier-torrents" that carry down ice-pieces and stones. On the east side of the southern lowlands, Markarfljót flows into the sea; it rises in Torfajökull, but also receives well-supplied feeders from Mýrdalsjökull; in the low land it divides into four arms which enclose the largest delta-land of Iceland, the so-called Landeyjar. Thjórsá, Iceland's longest river



Fig. 2. The river Jökulsá á Sólheimasandi. A ford.

(200 km.) rises in Arnarfellsjökull, but receives about one-half of its water-supply from Vatnajökull through its tributary Tungná; Thjórsá carries an immense volume of water and, in the cultivated district, is in several places one km. or more broad; above its mouth it forms an expansion or a saccate lagoon and is joined by a well-supplied arm of Markarfljót, named Thverá. The third and most westerly large river in the southern lowlands is Ölfusá which, for the longest part of its course (until the mouth of the tributary river Sog), flows under the name of Hvítá and issues from Hvítarvatn near Langjökull receiving, both on the plateau and in the cultivated district, many large affluents from both sides. In the neighbourhood

of Geysir, Hvítá forms the large waterfall Gullfoss. Towards the west, another river named Hvítá flows down through the district of Borgarfjörð; it carries a great volume of water and its lower course is navigable. In the north-western peninsula there are no large rivers, but in North Iceland many such occur, among others Blanda, which issues from Arnarfellsjökull and flows into Húnaflói. From the same Jökull issues also Hjeraðsvötn which flows through the district of Skagafjörð and empties itself into the fjord by two



Fig. 3. The river Hvítá flowing through the district of Borgarfjörð.

mouths. Three rivers of rather large volume — Hörgá, Eyjafjarðará and Fnjóská — enter Eyjafjörður. Then there is Skjálfandafljót which issues from Tungnafellsjökull and flows through the Bárdardalur; it has many waterfalls, among which Godafoss is the best-known. Jökulsá á Fjöllum, one of the best-supplied rivers of Iceland, empties into Axarfjörð and in its lower course falls through a deep cleft and forms Iceland's grandest waterfall, Dettifoss. In East Iceland two large rivers are noticeable, Jökulsá á Brú and Lagarfljót, both of which issue by many arms from the north edge of Vatnajökull and fall into Hjeraðsflói, after the latter river has expanded into a deep, oblong lake. Besides the numerous cataracts in the large rivers, there are also beautiful cascades (Fossar) in the smaller streams; of these the better-known are Hengifoss in Fljótsdalshjerad, Glymur in Botnsdalur, Dynjandi in Arnarfjörður in the north-western pen-



insula, and Skogafoss and Seljalandsfoss below Eyjafjallajökull. These cascades have a height of about 100 metres and more. The largest rivers, only, have been mentioned above, but in addition to these, hundreds of streams of greater or lesser volume occur, often with beautiful waterfalls and cascades in connection with picturesque clefts and rocks.

As mentioned above, the torrential and changeable glacier-rivers have a destructive influence upon the cultivation and vegetation of the plains. The greensward is torn off and large areas are covered by gravel, therefore the level country south of Vatnajökull is in several places turned into a desert almost destitute of vegetation except where special natural conditions afford a shelter from the destructive effect of the rivers. Where the action of the glacier-rivers is suddenly arrested by any natural phenomenon the level country again becomes quickly covered with plants. As an example may be mentioned the fact that Hverfisfljót, in the year 1783, was forced out of its bed by a great lava-stream, and a considerable stretch of land — Brunasandur — which had previously been irrigated by cold and torrential river-branches was freed from these, only a few clear streams of filtered glacier-water with a slight current issuing from the edge of the lava-streams and flowing down the level country; so that where in 1783 there was a gravelly and sandy flat without plant-life and without means of sustenance for human beings there is now a parish with seven farmsteads and abundance of meadows and pasture-lands for the sheep and cattle of the inhabitants. In itself the glacier-water is not inimical to vegetation; it is only the torrential current, the changeableness of the water-courses, and the low temperature of the water which have a destructive effect upon plant-growth; where these factors are not active, the glacier-water, with its contents of fine clay, is on the contrary a fertilizer; therefore in the neighbourhood of the mouths of the largest glacier-rivers, where there is only a slight current and the water has become warm on the way, fertile tracts of meadows are often found where the glacier-water is profitably utilized for irrigation. Water from rivers such as Thjórsá and Hvítá has, by analysis, been proved to contain an unusually large quantity of alkali and phosphoric acid.

**Lakes.** There are many lakes in Iceland, but the majority of them are of small size. The largest lakes — Thingvallavatn and



Thorisvatn — cover an area of only about 100 square km. each: the lake-surfaces occupy therefore only a very small part of the entire area of the country. The lakes are of very diverse origin, the basins having been formed by tectonic movements, ice-erosion, volcanic action and other natural agents. On the plateau where the outlet is slight, especially in the neighbourhood of the large Jökulls (ice-mountains) many lakes occur, in some places gathered in large groups, as Fiskivötn on Arnarvatnsheiði NW. of Langjökull, and Veðivötn W. of Vatnajökull; the melting snow and ice from the glacier-edges disappear in the nearest lava-streams and sandy tracts and then reappear and gather into basins many kilometres away from the glaciers from which they originated. In other places the lakes occur in the immediate neighbourhood of the glacier-edge, as Hvítárvatn and Hagavatn near Langjökull and Langisjór near Vatnajökull; the glaciers project into these lakes and calve their ice-bergs there; the water in these lakes is milky-white as in the glacier rivers. In some places lakes occur in between the glaciers (Grænalón near Skeiðarárjökull) or are dammed up in valleys by glacier-tongues. The best-known lake in Iceland is Thingvallavatn (105 square km.); it is situated in a new volcanic district bounded on the S. and W. by steep tuff-mountains and on the N. and E. by lava-streams which originate from the volcano of Skjaldbreið; these streams have afterwards flowed down between the two well-known fissures — Almannagjá and Hrafnagjá. It was here that the Icelandic Althing met in the time of the Republic. It appears as if the basin of the lake of Thingvalla was originally formed by subsidence along lines of fracture from SW. to NE.; this lake has a depth of 110 metres. In North Iceland Mývatn is the best-known lake; it is formed in a depression in the lava-stream and has a depth of only 2—7 metres; its bottom is lava and several craters project above its surface like islands, while the surroundings are very volcanic. Mývatn has received its name from the mosquitoes (mý) which are often quite a plague there. As in Thingvallavatn, trout are plentiful in this lake, but it is especially known as the abode of numerous birds, especially many different species of ducks. The group of lakes called Veðivötn consists for the most part of crater-lakes, of which the largest is called Stórisjór. In other places valley-lakes occur — deeply hollowed basins in the basalt — as Skorradalsvatn in Borgarfjörður and Lagarfljót in East Iceland, the surface of which latter lies 26 metres above sea-level while its bottom

lies 84 metres below the level of the sea. Lagoon-lakes, situated close to the coast, occur also, especially in North Iceland; the largest of them are Hóp, Höfðavatn and Miklavatn. According to the condition of the bars and the outlets the quality of the water of the lakes may often change quickly: sometimes they contain fresh water, sometimes brackish water, sometimes salt water. The fauna in these lakes is also subject to periodical changes. Sometimes marine animals immigrate through the outlets; at other times they disappear, and a freshwater fauna becomes dominant.

Fishing in the Iceland lakes is of great economic importance to the inhabitants. In the larger rivers and in many smaller streams, salmon is caught, and now the fishing is often rented out to English sportsmen, especially in south-west Iceland. Many rivers, and most of the lakes, abound in trout and salmon-trout (*Salmo alpinus* and *S. trutta*) which play a great rôle as a means of support of the inhabitants. The quantity of living organisms varies greatly according to circumstances; there appears to be most life in the shallow lakes, especially in those with lava-bottoms, in which warm or luke-warm springs are also sometimes found at the lake-bottom, around which plant- and animal-life collect. Some Phytoplankton (Diatoms) occurs in the lakes in South Iceland, but on the plateau and in North Iceland only Zooplankton (Daphnias) is found, and this is abundant. In Thingvallavatn, *Chara* and *Nitella* grow at a depth of 15—30 metres; in Mývatn there is a quantity of *Nostoc* which is found thrown up in great masses along the shores. In the lakes, there occur in addition, several species of *Linnæa* and *Pisidium*, and *Lepidurus* is frequently found in great quantities; there is, also, an abundance of gnat-larvæ and other larvæ which serve as food for the trout.

**Geology.** Iceland is almost entirely built up of volcanic rocks, none of which appears however to be older than Tertiary times. The foundation of the island is a depressed and broken basalt-plateau similar to the other Tertiary basalt-plateaus on both sides of the Atlantic Ocean, in East Greenland, the Færøes, Antrim in Ireland and on the islands of Mull and Skye. It is therefore assumed that in Tertiary times a continuous basalt-land extended across the Atlantic Ocean, that it subsided in Mid-Tertiary times and that Iceland and the Færøes are the remains of this land. In Greenland and on Skye the basalt rests on Jurassic strata, in Mull

and Antrim upon chalk; in Iceland, where the basalt formation has a thickness of at least 3000 metres, the underlying rock has not yet been found.

The principal rocks of which Iceland is composed are two, basalt and palagonite breccia; more than one-half of the surface and the rock-foundation of the country consists of basalt, but the palagonite formation, which is composed of breccias, tuffs and conglomerates of different age and which, taken as a whole, is younger than the basalt formation, forms an irregular band across the country, occupying an area somewhat smaller than that occupied by the basalt. Compared with these two formations, all other rocks and formations have quite an unimportant distribution. The basalt mountains, the precipitous walls of which often rise from the sea to a height of 600–1000 metres, are composed of layers of varying thickness, wedged in between each other; the thickness of the individual layers often decreases rapidly along a short distance until the layer disappears and gives place to another. In the basalt formation, beds of tuff and breccia sometimes occur between the basalt layers, but their amount is inconsiderable compared with that of the basalt. Dykes are frequent; the majority of them pierce down through the entire series of layers. Seen from a distance, the basalt-mountains with their steep, terraced walls, have a monotonous and gloomy appearance, but on closer inspection exhibit rather great variation. Some of the basalt layers are compact, others are coarsely crystalline, doleritic, porphyritic, amygdaloidal (with more or less completely filled vesicular cavities), slaggy, banded, etc. In some districts the basalt is cleft into beautiful columns; in others into more or less irregular, angular blocks; in others it has an almost slaty appearance. In the vesicular cavities of the basalt zeolites, quartz, chalcedony and calc-spar are often found. As a general rule the basalt layers have a slight inclination ( $3^{\circ}$ — $5^{\circ}$ ) from the coast inwards towards the tuff and breccia formations, which appear to fill a flat, saucer-like depression in the underlying basalt plateau; but many local deviations occur owing to dislocations and subsidences of larger or smaller areas of the underlying rock.

In the middle of the basalt-formation in Iceland (as also in the Færøes and in Ireland) rather considerable clay deposits are found with the impressions and remains of plants of Tertiary times; also lignite and compressed tree-trunks, all called in Icelandic “sur-tarbrandur.” This plant-bearing formation attains its greatest thick-

ness (20—50 metres) in the north-western peninsula and was originally deposited at one level, but was afterwards broken up by dislocations, so that it now occurs at different levels above the sea. The surtarbrand formation consists of diversely coloured layers of clay and tuff with intercalated layers of lignite and coal-slate; in many places leaves and fruits are excellently preserved in it, especially near Brjánslækur on the northern side of Breiðifjörður, and at Tröllatunga and other localities near Steingrímsfjörður; in this



Fig. 4. Mountains near Kolviðarhóll (tuff and breccia).

last place it can be seen that large Tertiary woods have been destroyed by pumice-eruptions and lava-streams. According to O. Heer the mean temperature of the year in north-west Iceland, at the time of these Tertiary woods, was at least  $9^{\circ}\text{C}$  — probably somewhat more ( $11^{\circ}$ — $12^{\circ}$ ); now the average temperature for the year in these places is only  $2^{\circ}$ . The most common tree in western Iceland at that time was *Acer otopterix*; its leaves are found in abundance and excellently preserved in the clay-layers; there occurred in addition *Sequoia Sternbergi*, *Pinus Steenstrupiana*, *P. microsperma*, *P. aemula*, *P. brachyptera*, *Betula prisca*, *Alnus Kefersteinii*, *Ulmus diptera*, *Quercus Olafssonii*, *Liriodendron Procaccini*, *Vitis islandica*, *Rhus Brunneri*, *Dombeyopsis islandica*, etc.

The Palagonite formation is composed of different kinds of tuffs and breccias, and in its upper divisions there is much moraine material and scattered glacial gravel, as also some ice-striated lava-



streams. The tuffs have usually a brownish-yellow colour owing to the intermixture of palagonite, a brown dully-lustrous alteration-product of tachylyte or basalt-glass, which constitutes the greater portion of the ground-mass of the rock; therefore the whole formation is often called the palagonite formation. The tuffs consist of lava-dust and lava-fragments with an abundance of glass-pieces (palagonite, tachylyte), slag and bombs; loose anorthite-crystals are often abundant. The breccias are distinguished from the tuffs by being



Fig. 5. Cliffs on Klifið (tuff and breccia). The Vestmannaeyjar.

more coarse-grained and containing larger, angular lava-pieces; the fragments consist of compact basalt, dolerite, pumice, slaggy lava and volcanic bombs; the separate fragments are often covered with a glassy crust. The palagonite formation is sometimes arranged in layers; sometimes not a trace of regular arrangement can be discerned. The tuffs and breccias have been formed by volcanic eruptions which chiefly ejected ashes and lava-fragments, and produced only a few lava-streams; the ruins of the numerous large volcanoes from which these eruptions proceeded may still be demonstrated. The palagonite formation is traversed by thousands of basalt dykes which branch and send out apophyses and intrusive sheets; very often the breccia and the tuff is filled with numerous hollow nodules and balls of basalt with a radially-columnar structure inside and



covered on the exterior with a crust of tachylyte. The tuff-formation appears to consist of several divisions the mutual relation of which has not, however, yet been elucidated.

All round Iceland, in both the basalt and the tuff formations, small patches of *liparite* occur. This rock occurs in small intrusive beds and dykes which, on account of their light colour, are distinguishable from the dark basalt and can therefore often be seen from a distance. The liparites vary very greatly both in colour and in structure, and in places where larger sections are exposed, the colouring is often richly variegated. Liparites are almost always accompanied by many closely allied, glassy rocks, especially pitchstones, which occur as dykes, perlites, sphærolites, obsidian and pumice. In south-east Iceland and on Snæfellsnes, veins of *granophyre* are found in some places. The rocky promontories on each side of the Bay of Lón in south-east Iceland consist of *gabbro*, probably of Tertiary age; this rock is also found under the névés of Vatnajökull, because many of the glacier-rivers carry down an abundance of pebbles of gabbro. The liparites and allied rocks, which on the whole cover an area of about 800 square km., are distributed all over the island, but most frequently in larger quantities in East Iceland. Liparite eruptions have taken place at all periods from the earlier Tertiary times to the present day; some volcanoes which have been active within historic times have ejected liparitic pumice. In the neighbourhood of Húsavík in North Iceland are found, near Hallbjarnarstadir, marine deposits with abundant shells of mussels and snails dating from the end of the Tertiary epoch, from the period called in England the *Red Crag*; these formations are found nowhere else in Iceland.

In central Iceland, where tuff and breccia form the foundation, large areas are covered by old *ice-striated lava-streams*. These lava-streams are distinguished from the lavas of the present day by their colour and structure. The modern lavas are usually dark in colour with a compact basaltic structure, while these ice-striated lavas have lighter colours and a doleritic structure. These dolerite-lavas, during the Glacial period and immediately after, flowed from dome-shaped lava-cones with large crater-openings, here and there still extant; or sometimes from large "Bedded Volcanoes" (Strato-Vulkane) the ruins of which — half destroyed by erosion — are still to be found here and there within the area of the palagonite formation. These ice-striated lavas are of different ages; some of them

have been produced before the surface assumed its present form, others have been formed after the country had in all essentials acquired the sculpture it has to-day; several of them have flowed down through valleys and hollows. Reykjavík is built upon such a doleritic lava-stream, and there the dolerite is much used for building purposes. In several places the glacial lavas are of considerable thickness (100—200 metres and more). Some larger volcanoes, which have been in eruption as late as within historic times (Eyjafjallajökull, Snæfellsjökull, Öräfajökull), began their activity even during the Glacial period and at that time discharged doleritic lava-streams. In several places in West and South Iceland large deposits of conglomerates occur, with rolled gravel and sand, alternating now and then with moraine material and ice-striated lavas; these resemble the “Nagelfluh” of the Alps and were perhaps formed in a similar manner.

During the Glacial period the whole island was wrapped in a sheet of inland-ice through which only a few small peaks projected here and there near the edges. The Jökulls (snow-fields) of the mainland probably extended on all sides down to the sea, for the bottom-moraines of that time are found everywhere, both on the plateau and in the lowlands; the lateral and terminal moraines which occur in the valleys and lowlands, date from a later period when the ice was retiring; it appears also that large masses of moraine-material occur here and there on the sea-bottom off the mouths of the fjords. The north-western peninsula was probably covered with a separate ice-sheet, from which numerous small glaciers, with intervening ridges free from ice, descended to the sea. The ice-sheet of the Glacial period had, on the interior plateau, a thickness of 700—800 metres. Ice-striated rocks occur all over the island, both in the high land, in the valleys, and in the lowlands, as also on islands and skerries. Large and small erratic blocks are found in thousands scattered over the whole of Iceland.

As mentioned above, it is assumed that Iceland, in the beginning of Tertiary times, was connected by a broad land-bridge with Greenland, the Færøes and Scotland; this land-bridge was a volcanic highland or plateau-land formed by innumerable lava-streams which originated principally from rows of craters and from fissures. The plateau, which had a height of 3000—4000 metres above sea-level, was towards the end of the Miocene period broken up and depressed; by this subsidence, perhaps in conjunction with

abrasion, the countries were separated and have never since been connected with each other. But Iceland was then, after the separation, considerably larger than it is now, the land extending 50—100 km.

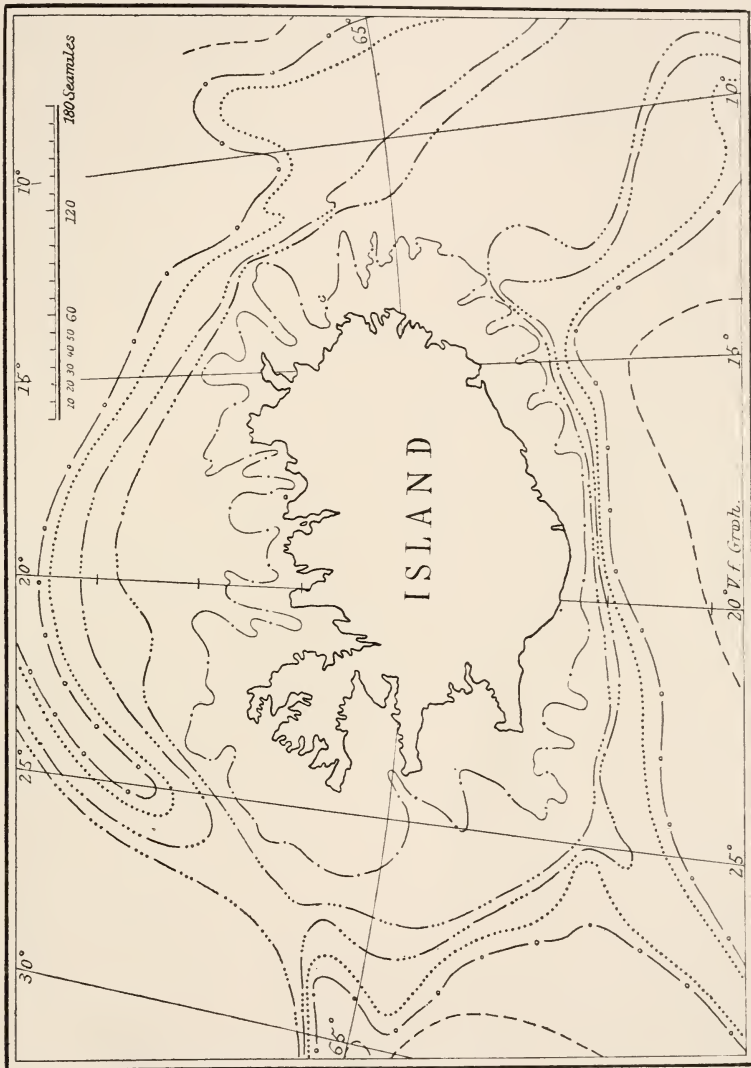


Fig. 6. Depth of the sea around Iceland.  
The lines from the coast outwards indicate depths of 100, 300, 600, 700 and 1000 fathoms respectively.

further out on all sides. The subsidence continued gradually, but perhaps with less intensity than before, through Pliocene times, and the submarine coastal platform, which occurs around the whole island and is limited by the 100 fathom line, was simultaneously formed by denudation: the abrasive action ended in the Red-Crag time.

In the Pliocene period Iceland was fissured transversely by numerous lines of fracture which caused violent volcanic action, by which the tuffs and breccias of the palagonite formation were produced. Along the same lines the volcanoes of the Glacial period and of the present day appeared. From the end of the Pliocene period to the present time the coast-line has been subject to considerable changes the boundary-values of which appear to be a positive displacement of 150 metres and a negative displacement of 250 metres of the position of the sea-surface relative to the land. At the end of the Pliocene, or during the earliest part of the Glacial period, the coast-line sank about 250 metres below the present level, and in the broad coastal platform which thus became dry land, erosion-grooves were formed leading off from each main valley. Now, each fjord and bay is continued out to the edge of this submarine platform by submarine fjords, as has been proved by the soundings taken of late years by the Danish Marine Department.

The marks left by a negative displacement of the coast-line in post-Glacial times occur around the whole coast, but are especially well-developed round the north-western peninsula. Everywhere along the rocky coast are found marine terraces of gravel, coast-lines and surf-terraces marked on the solid rock; in several places remains of shells are also found and sometimes bones of whale and walrus, also old drift-wood; sometimes far from the present line of coast. Round the north-western peninsula occur distinct and well-developed coast-lines and surf-terraces at two levels (70—80 metres and 30—40 metres above sea-level); such are also found on other parts of the coast, especially the lower line; the upper line is rarely as distinct as the lower one; in some places on the main land there appear to be indistinct marks of a water-level up to 100—150 metres. In South Iceland caves, hollowed out by the surf during the time of a higher water-level, are rather common, and marine clay-formations occur upon all the low land, the latter having been submerged during the final part of the Glacial period. In the clay-deposits in south-western Iceland, *Yoldia arctica* and other High Arctic molluscs are found at a level which corresponds with the higher coast-line (70—80 metres); other shell-mounds, with a fauna which resembles the present one, correspond with the level of the lower coast-line (30—40 metres), *Saxicava* is especially characteristic of these shell-mounds. Since the Glacial period the coast-line has retreated, but with some oscillations, and even now several indications may be



observed affording evidence of an upheaval of the land in our own day. Shortly after the Glacial period the climate was somewhat milder than it is now; in northern Iceland abundance of *Purpura lapillus* has been found in shell-mounds, and this still lives in the sea south of Iceland, but not in the colder water along the north coast. In bogs on the northernmost headlands, where birch woods no longer thrive, remains of *Betula alba* are found, while *Betula verrucosa*, which no longer grows in Iceland, has been found in the bogs of South Iceland.

**Volcanoes and Lava-streams.** Iceland is one of the most volcanic countries in the world; as mentioned above, the island throughout has been built up by volcanic activity which began early in Tertiary times and has continued to the present day. There are records to hand of 138 eruptions from 30 volcanoes within historic times, but many eruptions undoubtedly took place in early times which either were not recorded or occurred in the inland wastes and snow-fields without being noticed by the inhabitants. At the present time, 130 post-Glacial volcanoes are known in Iceland, and several volcanic vents have undoubtedly still to be found, or else have been effaced or destroyed by erosion. All the numerous volcanoes have, in the course of time, since the Glacial period, discharged enormous quantities of lava, and the post-Glacial lava-fields of Iceland cover an area of about 11 200 square km.; they occur over the country in vast expanses around the volcanoes from which they have originated. The majority of these lava-fields have been produced not by one but by numerous eruptions at various times, and the greater part of the lava dates from pre-historic outbursts. The largest lava-stream which has been poured forth during a single eruption within historic times, is that which issued from the craters of Laki — a row of craters formed in 1783; this stream covers an area of 565 square km.; and its mass occupies about  $12\frac{1}{3}$  cubic kilometres; it is probably the largest lava-stream upon the surface of the earth which, within historic times, has been known to flow out during a single eruption. The largest continuous lava-field in Iceland is Ödádahraun on the plateau north of Vatnajökull (600—1200 metres above sea-level); it was produced by numerous eruptions from more than 20 volcanoes, and covers an area of about 4000 square km. The lava-field, next in size, which originated from the many large craters near Veidivötn, west of Vatna-



jökull, and extends down to the south coast near Eyrarbakki, covers an area of 1550 square km. In the low land this lava-field is covered by a thick layer of soil upon which dense settlements have arisen. In addition, extensive lava-fields (1530 square km.), which originated from 28 volcanoes, occur on Reykjanes; and upon the plateau on either side of Langjökull, there are also other large lava-fields (1030 square km.) of which Hallmundarhraun is the best known; in it is the lava-cavern, Surtshellir, which is  $1\frac{1}{2}$  km. in



Fig. 7. Lava-stream (apalhraun); upon the outer south-west slope of Dyngjufjöll.  
(Phot. Heinrich Erkes.)

length. Large tracts of lava occur also around Hekla, near Mývatn, Kelduhverfi and in several other places.

The surface of the lava-streams varies greatly; often it is very rugged and jagged and is then, in Iceland, called *apalhraun*, and in the Sandwich Islands, *aa*. Such streams consist exclusively of porous and brittle lava and slaggy fragments heaped together pell-mell. Such lava-streams are comparatively narrow, with high edges which, seen from a distance, look like fences or ridges upon the level land. A lava-stream of this description is very difficult to cross, owing to the fragments being put together so loosely that they are disturbed by the slightest touch. Other lava-fields, especially the

large ones, have another variety of surface — lava-sheets — which may sometimes be level, but are more frequently broken and cracked in numerous directions; in Iceland they are known as *helluhraun*, in the Sandwich Islands as *Pahoehoe*. Upon the smooth surface, numerous tangled and twisted lava-ropes may be seen, bent in long curves following the undulating surface of the viscous lava. Sometimes this lava is compact, and without great irregularities of surface, but more frequently, by cooling, the surface has subsided and



Fig. 8. Sheet-lava near Frambruni. Slope of Trölladyngja on Odáðahraun.

(Phot. Heinrich Erkes.)

broken into large pieces, forming a number of hills, ridges, embankments and cauldron-shaped depressions, giving to it the aspect of a rough sea with high waves. Sometimes the surface of this sheet-lava is arranged in knots, curls and folds, all as smooth as hardened pitch. Beneath the lava-sheets there are often empty spaces, like drain-pipes and tunnels, and sometimes large caverns. Both forms of lava are sometimes found combined in the same stream. Long clefts often occur in the lava-streams, and sometimes enormous cracks, which are due to the subsidence of the substratum. Of lava-clefts of this description Almannagjá near Thingvellir is the most famous. In Odáðahraun there are also lava-clefts, 10—15 km. in

length. Groups of small slag-cones (craters) and lava-kettles (*Hornitos*) are very common in the lava-fields; they are often gathered together in hundreds upon a relatively small area and without any regularity

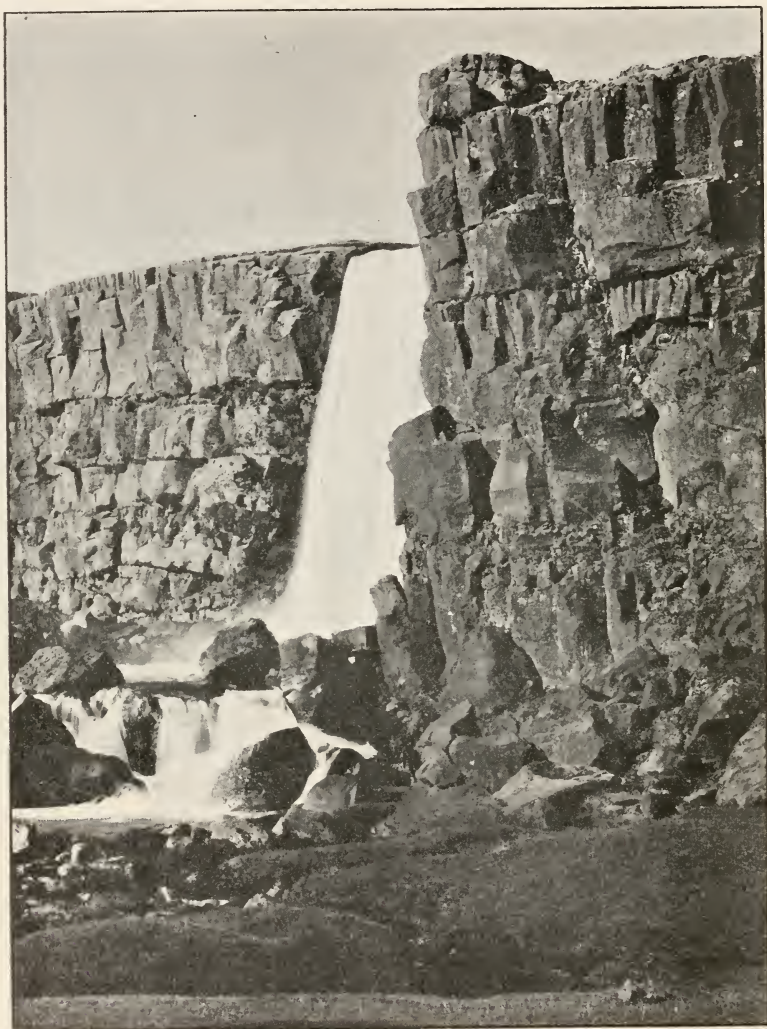


Fig. 9. Lava streams in vertical section (Almannagjá).

of arrangement. These slag-cones are secondary formations, usually associated with lavas which have overflowed marshy ground and lakes, and have thereby absorbed quantities of water-vapour; they are of frequent occurrence near Mývatn, on Reykjanes, and especially at Landbrot.



Large areas of Iceland are, moreover, covered with volcanic ashes, slags and bombs ejected by volcanoes. During the eruptions, the fine ashes are often spread out over a large part of the country and are sometimes carried by the wind across the Atlantic Ocean. During the Katla eruption in 1625, the ashes were carried to Bergen in Norway, and in 1845, ashes from Hekla were carried as far as to Germany, and during the Askja eruption in 1875 the volcanic dust was carried to the west coast of Norway in eleven hours forty minutes, and in another ten hours they travelled as far as Stockholm. Ashes and slag are thrown up into the air to a great height; on April 21, 1766, the ash-column of Hekla had a height of 5000 metres above the summit of the mountain, and it has often been higher still. Lava fragments and bombs are shot into the air to a great height and often fall at a distance from the place of eruption; during the Hekla eruption in 1510, a man was killed by a volcanic bomb at Skálholt, 45 km. from the volcano; during the eruption of the same mountain in April 5, 1766, a volcanic slag, as big as a man's fist, was hurled to Viðivellir in Skagafjörður, 165 km. from the mountain. The fine dust which fills the air during great eruptions, causes peculiar refraction-effects in the air; thus, during the Laki eruption of 1783, dust-clouds and unusually brilliant sunsets were common over the whole of Europe, North Africa and a part of western Asia. The ashes fell in such quantities in Caithness in Scotland as to destroy the crops; that year is still spoken of by the inhabitants as "the year of the ashie." The shower of ashes, together with the red-hot scoriæ ejected in an eruption, often causes considerable damage to the inhabited land. Pastures are buried beneath them or are scorched, and the coppice-woods often suffer severely. Whether the damage done by the ashes to pastures is permanent or not greatly depends upon their nature; the heavy basaltic ashes are especially injurious, as they can only with difficulty be carried away by the rain or by irrigation. When, however, the layer of ashes is thin it gradually is absorbed into the soil, by the grass growing up above it. In the neighbourhood of larger volcanoes, several layers of ashes, one above the other, are found in the soil. The light, liparitic pumice-ash, which is rarer, is less injurious, as it is quickly carried away by water. Sometimes the ashes discharged by a volcano contain a great quantity of acids; during the Laki eruption of 1783, the ashes were so acid that they burnt holes in the burdock leaves, and left black patches on the

sheep's skins, and the hoofs of the sheep turned yellow when they walked amongst them; while the rain which fell from the dust-clouds, is said to have been so sharp and biting that it was painful where it fell on the hands and face. The volcanic eruptions, on the whole, have had a very injurious influence upon the plant-distribution in the volcanic regions of Iceland. During the eruptions a great number of sheep and cattle die from want of food or from its unwholesome nature, and of various diseases caused by the ashes eaten with the fodder. No eruption has however been so disastrous as the eruption of the Laki crater-rows in 1783. In the winter which followed, and in the spring of 1784, the sheep and cattle suffered from all kinds of diseases owing to the unwholesome food, and died by scores. On many farmsteads the entire live-stock died out, and the following year there died in the whole of Iceland 11,500 cattle, 28,000 ponies and 190,500 sheep — about 53 per cent of all the cattle, 77 per cent of the ponies and 82 per cent of the sheep. Then came a famine, which carried off 9500 of the inhabitants, about one-fifth of the total population of Iceland at that time.

In Iceland there are several types of volcanoes. Usually, by a volcano is understood a large hill or mountain, more or less conical in form, which is ignivomous, discharging lava-streams and ejecting ashes and fragments of lava. Volcanoes of this description occur in Iceland, but are not common; seven or eight such volcanic mountains are known, which resemble externally the well-known Italian volcanoes of Vesuvius and Etna, without however being so regular in form; they are built up of alternating layers of ashes, lava and slag, and usually resemble truncated cones with a crater at the top, and a considerable angle of inclination (at the base  $8^{\circ}$ — $15^{\circ}$ ; at the top  $20^{\circ}$ — $35^{\circ}$ ); the majority of them have their summits covered with snow and glaciers. Of these volcanoes the largest and best known are Örafajökull, Snæfellsjökull and Eyjafjallajökull. Hekla is also built up of alternating layers of lava and tuff, but is not conical. Its shape conforms to an elliptical ridge, rent down its major axis, and studded with a row of craters along the line of fissure. Another type of Icelandic volcano are the dome-shaped "lava-cones" (*dyngja*, pl. *dyngjur*) — larger or smaller volcanoes, built up entirely of lava-streams, without any intermediate layers of tuff or slag. Volcanoes of this description, which are also found in the Sandwich Islands, are distinguishable from the country surrounding them as shield-shaped cones, and their altitude is low



compared with their extent. The largest have an altitude of 1400—1600 metres, and a diameter of 10—15 km. On such dome-shaped lava-cones the angle of inclination at the top of the mountain is only slightly greater than near the base, seldom exceeding  $7^{\circ}$ — $8^{\circ}$ , and more frequently still less, often only  $1^{\circ}$ — $2^{\circ}$ . The summit of such volcanoes consists of a circular or elliptical mouth or depression, often of large dimensions, some having a diameter of 1000 metres or more. The walls of the depression (crater) are usually



Fig. 10. Row of craters.

cleft by concentric fissures, so that the descent from the lip to the bottom of the crater is, as it were, a series of steps. The sides of these volcanoes are entirely covered with knotty sheets of lava, and long tunnels and caves are very common in the sides of the volcano. In some cases the depression is filled with lava to such an extent, that the only indication of the circumference is a ring of small lava-pinnacles and lava-ridges. The immense lava-waste of Odáðahraun was mainly formed by outpourings from this type of volcano, of which Trölladyngja (1491 metres) is the largest. Another well-known volcano of this description is Skjaldbreið near Thingvellir. Of post-Glacial lava-cones, 16 are known from Iceland. These lava-cones were also very common during the Ice Age.

The greatest amount of lava which has been poured forth in

Iceland, issued from volcanic fissures and crater-rows; these are not volcanic mountains, but rows of low craters established along the direct line of a fissure, more frequently upon level land. Of this kind of eruptive vent, 87 are known from Iceland at present. Each of the craters in such a chain occurs independently and is built up of scoriæ and lava. They are usually low, rarely exceeding a height of 100—150 metres, while the majority of them are even considerably lower; they are often very irregularly formed and composed of several rings. Some crater-rows are very long; they often attain a length of 5—10 km., and some are longer still, as for instance, the Laki crater-row of 1783, which has a length of 30 km., and contains about a hundred separate craters of various sizes. Some crater-rows are so small that they resemble toy-volcanoes. In some places the lava has welled up out of fissures in large streams without any visible craters. The largest of these fissures is Eldgjá, north of Mýrdalsjökull; it has a length of 30 km., and has poured out lava-streams sufficient to cover an area of about 700 square km. In some places “explosive craters” occur, cauldron-shaped depressions produced by a single volcanic explosion. The best known of these craters is Viti, on the side of Mount Krafla, north of Mývatn. It was formed by a sudden outburst on May 17, 1724. For a long time afterwards there was a large, boiling slough at the bottom of the crater, but this is now converted into a greenish-coloured quiescent lake. The majority of the volcanoes in Iceland are basalt volcanoes, and have poured out streams of basaltic lava, and ejected basaltic slag and ashes. Only in the neighbourhood of Torfajökull liparitic volcanoes occur — of post-Glacial origin, and of peculiar aspect — which have poured out lavas rich in silica. The interior of the lava-mass is grey or reddish brown, but the surface of it is jet-black, as it consists of obsidian, covered here and there by light, almost white, pumice. The largest liparitic lava-streams are those called Hrafninnuhraun and Dómadalshraun. In some places streams of liparitic blocks in a half-melted condition have flowed out from craters in the mountain-sides, and several volcanoes have ejected liparitic pumice, as for instance, the volcano of Askja, 1875. Many volcanoes in Iceland are buried beneath the snow and the glaciers, and as mentioned above, when they break out into eruption, large masses of ice are melted and the glaciers burst, which causes the neighbouring level lands to be inundated by enormous floods of water, with huge fragments of ice tossing on

its surface. The Katla eruption, in this way, converted thickly inhabited and fertile tracts into deserts, and in 1362 Öraefajökull destroyed, in the same way, two parishes, sweeping away forty farmsteads with their inhabitants and live-stock and all else, out into the sea.

The best-known Icelandic volcano is Hekla. It has been the scene of 21 eruptions during historic times; next in importance comes the glacier-volcano Katla of which 13 eruptions are recorded.



Fig. 11. Kverkfjöll, a volcano on the northern edge of Vatnajökull; seen from Hvannalindir.  
(Phot. J. P. Koch.)

Submarine eruptions have taken place some ten to twelve times near Eldeyjar off Reykjanes, whereby new islands have had their origin; but these have disappeared again. Several volcanoes are present beneath the ice-cap of Vatnajökull, but the foci of eruption are not known for certain. During the last two centuries, from 30 to 40 eruptions have been recorded from the snow-fields of Vatnajökull. During several of these eruptions the snow and ice on Skeiðarárjökull, on the southern side, partially melted, and enormous torrents of water were discharged. Occasionally Brúarjökull, on the northern side, has been very active. On Reykjanes there are numerous pre-historic volcanoes and rows of craters, and in three or four places eruptions have taken place since there have been settlements on

the island; one of the most active volcanoes on Reykjanes is called Trölladyngja. The best-known volcano near Mývatn is Leirhnúkur, but besides this, many smaller crater-rows and separate craters occur; the volcanoes near Mývatn were particularly active during the years 1724—30. In the centre of Odáðahraun rises the volcanic mountain-group Dyngjufjöll with the crater-valley of Askja; it is one of the largest volcanoes of Iceland. The crater-valley, which is surrounded by circular mountain-walls, covers an area of about 55 square km. In the south-eastern corner of it there is a deep volcanic depression with a lake; at the edge of the latter a new crater opened on March 29, 1875, and discharged an enormous quantity of pumice over the eastern part of Iceland and, as mentioned above, the dust was carried as far as to Scandinavia. The greatest eruption which has taken place during historic times in Iceland was the eruption of the above-mentioned crater-rows of Laki in 1783. The lava which poured forth filled valleys, altered the course of rivers and destroyed several farmsteads, fertile meadows and extensive pastures. North of Iceland submarine volcanic eruptions have occasionally taken place.

Almost all the volcanoes of Iceland are associated with fissures in the tuff and breccia areas of the palagonite formation. In the southern part of Iceland all the mountain-ridges, valleys and rivers exhibit a decided dependence on tectonic lines of deeply situated fracture from SW. to NE. Open fissures in the surface, all the numerous crater-rows, and the lines joining the volcanoes, have a similar direction. Moreover, hot springs — both alkaline springs and sulphur springs — are arranged along the same lines. In North Iceland, on the other hand, the tectonic lines and the fissures and volcanoes, have generally a direction from S. to N. Both these directions probably are combined in a curving band of fracture-lines which lies across the island. In the basalt plateaus of the west coast there are several cauldron-like fissures and concentric fractures, and along the southernmost of these depressions, which extend over both the tuff and breccia areas around Faxaflói, the volcanoes and hot springs are arranged in a semicircle.

Earthquakes are very frequent in Iceland not only in connection with volcanic eruptions, but also apart from them; in the latter case they are chiefly confined to three districts with well-marked natural boundaries. All the greater earthquake shocks are tectonic



in origin; that is to say, they are due to movements and subsidences of large tracts of land bounded by dislocations and fractures of the ground. In North Iceland, between Skjálfandi and Axarfjörður, where the new volcanic tuff district extends to the coast, violent earthquakes are frequent, especially in the neighbourhood of the trading-station of Húsavík. The earthquakes of 1755, 1872 and 1885 were especially serious and did great damage in these districts. At Faxaflói there is another earthquake-area where minor shocks are very common; they are usually most violent on Reykjanes, especially in the neighbourhood of Krisuvík, and at the extreme point of the peninsula, near the lighthouse. The third earthquake-area comprises the southern lowland area between Reykjanes and Eyjafjallajökull. This district has frequently suffered from violent and destructive earthquakes which have caused great loss of human life and of property. In modern times the earthquakes of 1784 and 1896 have been especially destructive. The former (Aug. 14—16) completely ruined 92 farmsteads, and damaged 372 houses and 11 churches. In August and September, 1896, the earthquake shocks were even more violent. Great chasms were rent in the earth, some as long as 15 km.; water-courses were altered and the position of hot springs changed; quantities of hugh fragments of rock were loosened from the mountain-sides; 161 farmsteads were hurled down, and 155 more were greatly damaged; in fact, every house in this area sustained some damage. By each of these violent earthquake shocks a limited tract of land was put in movement. Occasionally, North Iceland has been shaken by volcanic eruptions which originated under the sea off the north coast of the island; this was the case in the years 1838, 1899 and 1910.

Hot alkaline springs occur in hundreds in Iceland, scattered all over the country, sometimes singly, sometimes in groups. At the present time 677 hot and boiling springs are known in 162 localities, and the majority of them are closely dependent upon the fracture-systems of the island. Earthquakes exert great influence upon these springs; many disappear or are altered, and new ones are formed. The surfaces of the springs have any temperature up to boiling point. Tepid springs which can be used for bathing are called "laugar," boiling springs "hverar." Some of the latter throw up jets of water as Geysir does; but otherwise the boiling springs may be divided into five classes: (1) springs which are constantly



spouting, (2) intermittently spouting springs, (3) alternately spouting springs, (4) constantly boiling springs which do not spout, (5) springs with a high temperature and a quiet surface or which boil quietly in the middle. All the boiling springs deposit siliceous sinter. The most famous hot spring is Geysir, in the vicinity of Haukadalur in South Iceland, in the centre of a group of other boiling springs. This group of springs was mentioned for the first time in 1294 and has often undergone alteration by earthquakes, especially in 1630 and 1789. Geysir's eruptions now take place very irregularly and many days may intervene between them. At the end of the 18th and the beginning of the 19th century, Geysir's activity was at its maximum, and it could throw up fountains of water to a height of 50—60 metres, whereas now the water rarely rises above 30 metres. The neighbouring hot spring Strokkur, began its activity in 1789 and ceased during the earthquakes of 1896. At first Strokkur threw up higher fountains of water than did Geysir, not only boiling water and steam, but also cold water. Other large groups of hot springs are found near Reykir in Ölfus, in Reykholtsdalur, on Hveravellir on the plateau NE. of Langjökull, and in many other places.

Sulphur springs occur in abundance in the volcanic districts, but not outside the palagonite-formation; also alkaline springs are common in the basalt districts. The alkaline springs are found upon the level land, in valleys and upon mountain-sides where there is much underground water, but the sulphur springs commonly occur upon mountain ridges and other dry localities where the water has an outlet through the underlying lava, etc. Several of the solfataras deposit a considerable amount of sulphur in small heaps where the sulphurous vapours rise from the soil. Sulphur from Iceland had a commercial importance even in the 13th century, and the trade in sulphur was especially lucrative in the 16th century. Since that time the export of it has gradually decreased and now has entirely ceased. The sulphurous vapours which rise through the clefts and cracks in the earth have a great effect upon the neighbouring rocks, which are transformed and decomposed in various ways — coloured clays, gypsum, iron-alum (Halotrichit), etc. being formed. The mountains which have been penetrated by the hot sulphurous vapours are easily recognizable at a long distance, owing to their naked and discoloured appearance; they are always light-red, yellow and white in colour and are entirely destitute of plant-

growth. While plant-growth is abundant in the neighbourhood of the alkaline hot springs, from the vicinity of the sulphur springs it is almost absent. In places where surface-water or underground water is found, mud-holes are formed, or larger or smaller sloughs, in which clayey mud of various colours boils and bubbles; it is sometimes ejected a few feet upwards, whereby crater-like mounds are formed around the larger pits, bearing a weird resemblance to



Fig. 12. Solfataras of Krisuvík.

large cauldrons of boiling porridge. The majority of the sulphur springs occur on Reykjanes, in Hengill, near Krisuvík and at Cape Reykjanes where the large slough of Gunna is well-known. Moreover, extensive sulphur-spring districts (Námufjall, Krafla, Fremrínámur) occur near Mývatn, and Kerlingarfjöll near Arnarfellsjökull is another, upon the interior plateau. Carbonic acid springs (*ölkeldur*) and Mofettes occur here and there, especially on Snæfellsnes in western Iceland; the best-known carbonic acid spring is found near Raudimelur in Hnappadal. Ores, metals and stones of any great commercial value are not found in Iceland. Here and there some lignite occurs which is utilized by the neighbouring inhabitants. The gathering of sulphur is no longer lucrative, but,

as already mentioned, in East Iceland calcareous spar is quarried at Helgustaðir near Reyðarfjörður and is used by the makers of optical instruments.<sup>1</sup>

<sup>1</sup> For fuller notes on the Physical Geography and Geology of Iceland the reader is referred to the following papers by Th. Thoroddsen: *Island. Grundriss der Geographie und Geologie*: Justus Perthes, Gotha, 1906 (358 pages). *Lýsing Islands*, Köbenhavn, 1908—1911, in 2 vols (365 and 673 pages). *Explorations in Iceland during the years 1881—98* (*The Geographical Journal*, London, 1899, Vol. XIII, pp. 251—274, 480—513). *Vulcane im nordöstlichen Island* (*Mitteilungen d. k. k. Geogr. Gesellschaft*, Wien, 1891, pp. 117—145, 245—289). *Geological Map of Iceland*. Surveyed in the years 1881—98. Edited by the Carlsberg Fund. Copenhagen, 1901, Scale 1 : 600,000.

## II. CONDITIONS PERTAINING TO SURFACE AND SOIL.

**A**FTER having thus given a brief, general survey of the orographical and geological conditions and having described the substratum and general structure of the island, we will now pass on to a description of the surface itself, with which plant-growth is more particularly associated. As mentioned above, Iceland is built up of basalt, tuffs and breccias, but basalt is the fundamental rock; the tuffs and breccias are, for the most part, nothing else but basalt split and pulverized. The mineralogical and chemical composition of the soil is therefore essentially the same over the entire island, provided the siliceous liparites are excepted which have no effect of any importance to the whole.

Seen from a distance, the basalt mountains usually appear to be steeper than they are in reality, and the small terraces or steps of the layers of basalt are not distinguishable in the higher part of the mountain from a distance except when they are snow-covered or when, as rarely happens, a scanty vegetation (especially mosses) has been able to gain foothold upon the narrow ledges. The rule is that the steps of the basalt mountains become broader as the base is approached. At the top the separate layers project as a narrow ledge which is only half, one, or two metres broad, but lowest down in the valleys, and nearest to the sea the separate layers form enormous terraces which may attain a breadth of  $\frac{1}{4}$ — $\frac{1}{2}$  km. or more. The upper surface of these broad terraces is covered with gravel and clay, and sometimes with a scattered plant-growth, or sometimes with a continuous vegetation, with bogs or swamps; there, enormous, elongated snow-wreaths may persist far into the summer. On basalt mountains erosion is more active on the sunny side, therefore the other side is steeper and more sparsely covered with plants. On the sunny side the average inclination is usually



only  $20^{\circ}$ — $25^{\circ}$ , but upon the other side  $30^{\circ}$ — $35^{\circ}$ . There are, however, a few basalt mountains which are much steeper than this: for instance Skessuhorn near Borgarfjörður, which has an inclination of  $48^{\circ}$ . In the numerous erosion-channels on the mountain sides, where gravel and stones are constantly rattling down and avalanches are frequent, it is difficult for the plants to gain foothold. The ridges between the mountain streams are therefore more closely covered with plants but, as already mentioned, a continuous plant-



Fig. 13. Basalt mountains with snow-wreaths (Isafjörður).

covering rarely extends higher than half-way up on the basalt mountains. In olden times the mountain sides were in very many places clad with coppice woods, but these disappeared at an early date, partly owing to the havoc wrought by sheep and partly to man's lack of foresight. Now only some stunted shrubby birches are to be seen upon inaccessible cliffs, where they are beyond reach of man and beast, even with the utmost exertion. Upon mountain-sides deprived of their birch-copses, avalanches of snow and stones have suffered no hindrance, so that all soil and plant-growth have disappeared, thus turning the mountain-sides into naked, gravelly and rocky slopes. In some districts such changes have taken place



even as late as in the 19th century. Where the basalt mountains are not too steep nor the mountain-streams too torrential, the flat gravel-cones upon the valley sides, below the notches in the mountain, are often overgrown with plants. These gravel-cones often underlie the home-fields of the farmsteads.

In the fjord districts of Iceland the vegetation upon the basalt mountains differs considerably in passing from the sea inwards. Owing to the effect of the sea-water, the violent storms and the rawness of the climate, the outermost points are comparatively poor in plants, while the vegetation increases inwards towards the valley, and in the bottom of the valleys, especially on the north-western peninsula, remains of coppice woods are often found; but woods could not thrive out along the fjords, still less at the extreme points. Where the basalt does not occur as steep cliffs and is not covered by loose layers of clay, glacial gravel and soil it is usually strewn with loose sharp-edged fragments, split and torn off by frost. The severance of these fragments usually follows the cleavage of the basalt, and they are sometimes slaty and in thin plates, a condition which is especially common in the uppermost part of the basalt formation. Upon the split and torn basalt in the uppermost part of the mountains, plants have difficulty in gaining foothold, especially when the climate is as raw and stormy as is the case in Iceland. Therefore, large areas of the higher-lying basalt districts are extremely poor in plant-life even in places, where according to the situation, the conditions might be expected to be somewhat more favourable.

The landscape in the tuff and breccia districts has a different appearance. Basalt mountains usually have sharp, and breccia mountains soft outlines. Those areas of the cultivated districts and on the lower spurs of the highland which are built up of tuff and breccia have often a more or less undulating appearance; the mountains are broken down into numerous rounded ridges and protuberances with intervening stretches of level ground and valleys of irregular shape; but here and there are seen tabular mountains or promontories with steep sides and a flat surface, where the basalt or dolerite has covered and protected the tuff and the breccia. On the plateau, where through centuries storms have been continually altering the sculpture of the surface, the soft tuff-mountains have suffered in particular; here the tuff-ridges are connected into irregular chains which have been eroded in every possible way, and often resemble fantastic ruins with numerous sharp peaks, protuberances

and knolls separated by sandy areas and labyrinths of branched clefts and small valleys. Tuff mountains, owing to the loose nature of the rock, are relatively poor in water as the latter often disappears into the ground, and does not appear until at a distance from the mountain. This is especially the case with the tuff-mountains on the plateau where, during summer, not a single stream or spring is met with for long distances, but only large, deep, dry river-beds and water-courses filled with coarse gravel and large



Fig. 14. Remaining portion of a "móhella" upon a wind-eroded gravelly flat (ðrfoka).

boulders. These river-beds are due to the melting of the snow in spring or during periods of thaw in winter when, for a short time, they are all filled with torrential floods of water.

The surface of the breccia mountains is usually concealed by loose, angular and porous fragments of lava which have been disintegrated from the breccia; the nature of the rock is often seen only in clefts and in a few prominent protuberances and projecting rocks. The power of resistance of the rock against the action of water and wind differs however greatly, because tuff and breccia are of all possible degrees of hardness, although a loose texture is the most common. Tuff is easily disintegrated, and water and wind

carry the finer palagonite-dust down into the valleys or to distant quarters of the island where it is deposited and retained by the vegetation, frequently forming thick layers (móhella). The heavier lava-fragments which have thus been deprived of matrix are left behind. On stretches of level ground the lava-gravel, thus loosened, sometimes attains a thickness of several metres. As a general rule the surface of the tuff-mountains is much affected by the action of water and air and along the sides of the fissures the effects may be traced far down. Sometimes these fissures are filled with zeolites, calcite or gypsum; and sometimes the mass which fills the fissures is harder than the surrounding rock so that the surface presents the appearance of a network of raised lines, while the tuff in the intervening spaces has been disintegrated and carried away. On the ridges and peaks of several tuff mountains the surface is, as it were, pock-marked with numerous small irregular hollows, channels and pot-holes which are probably due to the combined action of water and drifting sand. There are often a great number of clefts and fissures in the tuff-mountains which can sometimes be seen from a great distance because of the plant-growth which retreats to them to find shelter from the storm. On the whole the varied forms of surface in the tuff districts greatly influence the details of the distribution of the plants of the place.

As tuff is far more easily decomposed than basalt, soil is formed more quickly upon tuff-mountains in cases where external factors such as sand-drifts and storms do not interfere. Therefore on the tuff and breccia mountains of southern Iceland there is a thick coating of soil and a luxuriant plant-growth right to the verge of the mountain; this is rarely the case on basalt mountains. Even on steep mountain-sides of tuff and breccia there exists a luxuriant vegetation of various species. This is especially conspicuous in Mýrdalur (south of Mýrdalsjökull) where, for instance, the extreme point of Reynisfjall is densely covered with plants. A luxuriant vegetation is also found in Víkurklettur and in several other places. On the whole, as mentioned above, it is characteristic of the lower mountains, south of the great Jökulls, to be covered by a comparatively luxuriant plant-growth, while the level country is barren, owing to the destructive action of the glacier-rivers. In the case of the sea-fowl cliffs, where manure is supplied by the sea-fowl, such tuff-mountains are far more densely covered with *Cochlearia*, *Archangelica*, etc., than are the basalt mountains.

In Iceland all which lies above 500 metres is a complete desert; this is also true of great parts of all that lies between 300 and 500 metres; at this altitude there are, however, rather extensive bogs covered with *Carices* and *Eriophorum*, especially towards the west (N. W. of Langjökull). Larger and smaller desert-areas are also found lower down; in some places they extend even to the sea, but in such cases they owe their origin to special circumstances — the destructive influence of glacier-rivers, volcanic eruptions or blown sand. In many inhabited districts the greater part of the surface consists of a rocky flat with scanty vegetation; a dense plant-growth such as that found in meadows, bogs and heather-moors covers only a very small part of the entire surface of the island, perhaps not more than 1500—2000 square km.; but the amount so covered cannot be stated with any certainty. The interior plateau owing to its height above sea-level and its climatic conditions will probably never be of any greater importance, as regards the livelihood of the inhabitants, than it is at the present time. Considerable tracts of the lower-lying parts of the plateau (afrijetir), in spite of the very poor herbage, are used as summer-pastures for the hardy Icelandic sheep which are driven up into the mountains about the end of June and fetched home again in the middle of September. No small percentage, however, of these sheep perishes yearly by venturing too far into grassless wastes, falling into rivers and down clefts, being overcome by snow-storms, becoming a prey to foxes, etc.

The snow-line and the glaciers form the upper limit of plant-growth; but from thence down to about 500 metres above sea-level, individual plants usually occur widely separated; there are, therefore, virtually no habitations on the plateau. As the height of the snow-line in the different parts of the island varies greatly, so similar laws govern the occurrence of the habitations, which are closely associated with the plant-growth. The highest snow-line occurs in north-east Iceland, and there the habitations also extend furthest upwards. Three parishes are found on the plateau itself, viz. Mývatnssveit at 300 metres above sea-level, Fjallasveit at 400—500 metres, and Jökuldalsheiði at 500—530 metres. In the last two the number of the farmsteads and of the people has been subject to very great fluctuations. The inhabitants of these parishes maintain themselves almost entirely by sheep-rearing. In Mývatnssveit the conditions are however more favourable, as it is situated at a



lower level, is sheltered by several high mountains and has moreover a rich fishery in Mývatn. The district of Fjallasveit is chiefly covered with blown sand, and the plants growing on the sand-dunes and sandy flats, viz. *Elymus arenarius*, *Salix glauca* and *S. lanata* and *Carex incurva*, serve as fodder for the sheep, which thrive well. These plants are cut and gathered during autumn for winter-use. It is, however, difficult to keep cows; and on account of the weather, neither potatoes nor root-crops will thrive. The climate is also far more severe than at the coast; the annual mean temperature in Mödrudalur is  $-0.8^{\circ}$  C. In these districts the snow-line has a height of 1300—1400 metres above sea-level, and the highest limit at which habitations occur is 530 metres. On the north-western peninsula, to the extreme north the habitation-limit occurs at only 80 metres above sea-level, and the snow-line at 400 metres; more to the south, on the same peninsula, at about 130 metres, and the snow-line at 650 metres. For comparison with the height of the snow-lines given above I give in the following pages a list of the inhabited farmsteads situated at the highest levels in the different parts of the country, because they give an indication of the limit of the more densely plant-covered, inhabited country upwards towards the wide expanses, poor in plant-life, in the interior. The settlements in the uppermost valleys and in some parts of the plateau are by no means fixed; in years when severe weather occurs, with cold and damp summers, some of these farmsteads are abandoned, but are again inhabited when more favourable weather sets in. The areas above the populated districts, between these and the desert proper, are too poor in plant-life to be inhabited, but they are of great importance as summer-pastures for sheep and ponies.

#### Heights of the uppermost farmsteads above sea-level in metres.

##### Upon the northwestern peninsula.

Smidjuvík SE. of Cape Nord.....	80 metres
Skógar in Mosdal at Arnarfjörður....	82 —
Hlidarsel at Steingrímsfjörður.....	128 —

##### Near Faxaflói.

Fornihvammur in Nordurárdal.....	170 metres
Gilsbakki in Hvítársíða.....	175 —
Fljótstunga .....	232 —
Kalmannstunga .....	218 —
Hæll in Flókadal.....	174 —



Upon the peninsula of Reykjanes and in its immediate neighbourhood.

Vigdísarvellir NE. of Krisuvík.....	122	metres
Kolvidarhóll <sup>1</sup> near Hengill.....	262	—
Nesjavellir S. of Thingvallavatn.....	172	—
Svartagil N. of the above lake.....	182	—

Near the Southern Lowland.

Austurhlid on the way to Geysir....	163	metres
Haukadalur N. of Geysir.....	104	—
Tungufell S. of Gullfoss.....	148	—
Stórinúpur in Hreppar.....	135	—
Galtalækur W. of Hekla.....	142	—
Selsund SW. of Hekla.....	155	—
Raudnefsstaðir NW. of Tindfjallajökull.	239	—
Barkarstaðir in Fljótshlid.....	134	—

South of Mýrdalsjökull and Vatnajökull.

Höfdabrekka in Mýrdalur.....	128	metres
Svartínúpur in Skaptártunga.....	273	—
Holt in Sida.....	172	—
Eintúnaháls in Sida.....	227	—
Skaptafell (Bölti) in Öræfi.....	161	—
Viðidalur in Lón <sup>2</sup> E. of Vatnajökull..	439	—

In the valleys of East Iceland.

Mýrar in Skriddal.....	183	metres
Kleif in Fljótsdal.....	126	—
Hákonarstaðir on Jökuldalur.....	310	—
Hauksstaðir in Vopnafjörður.....	195	—

Upon the plateau between Jökuldalur and Bárdardalur.

Viðirhóll on Jökuldalsheidi.....	533	metres
Lón.....	531	—
Mödrudalur on Mödrudalsfjöll.....	469	—
Viðidalur.....	462	—
Grímsstaðir.....	432	—
Viðirhóll.....	415	—
Reykjahlíd at Mývatn.....	292	—
Gautlönd.....	279	—
Krákárbækki.....	363	—
Svartárkot.....	409	—

In the valleys of North Iceland.

Ishóll in Bárdardalur.....	368	metres
Reykir in Fnjóskadal.....	223	—
Tjarnir in Eyjafjörður.....	223	—
Bakkasel in Öxnadalur.....	350	—
Gilhagi in Skagafjörður.....	227	—
Mardargnupssel at Svínadalur.....	395	—

<sup>1</sup> In reality only an inn for travellers.

<sup>2</sup> Not built until 1840; abandoned in 1842—1882; rebuilt 1883.

The surface of the interior plateau, with the exception of the glacier-covered areas, consists of deserts of stones, lava, gravel and blown sand. Where the underlying rock is basalt, the surface of the plateau is usually strewn with angular blocks of basalt, often in irregular heaps. Occasionally ridges are found, covered with gravel and blocks of glacial origin, but blocks split by frost are decidedly the more frequent upon these ridges. On the plateaus above the fjord districts of East Iceland, extensive areas are covered with angular blocks of basalt, but usually this layer of loose blocks is relatively thin. Similar conditions are met with in the north-western peninsula and on the mountains of North Iceland; but in the interior of the country glacial materials and the more recent formations preponderate. In that part, therefore, the greater part of the area consists of ice-striated ridges of dolerite, post-Glacial lavas, old bottom moraines and blown sand. Ice-striated streams of old dolerite-lava occupy vast areas in the interior. North of the great Jökulls the dolerite lavas may be traced continuously from Arnarvatn in the west to Snæfell in the east. Here and there the dolerite is covered with recent lava, and the closer the Jökulls are approached the thicker becomes the surface-layer of glacial gravel. As already mentioned, these monotonous, bluish-grey, stony deserts present an extremely desolate appearance. The only points upon which the eye can linger are scattered snow-drifts and large erratic blocks lying scattered upon the ridges. The landscape has undoubtedly remained for centuries unaltered in appearance: it must have looked as it does now, immediately after the snow-fields of the Ice Age had retired. There is no sign of life, and deep silence reigns over the land. The dolerite ridges, as has been already said, are covered with blocks rent by frost between which ice-striated domes protrude here and there. All the upper faces of the stones are dully polished and seamed by wind-abrasion. For days the traveller may see nothing else but gravel and ridges of rocks in endless succession like waves upon the sea; while as regards plants, only at intervals of 10 to 20 metres may a few stunted specimens of *Armeria maritima*, *Salix herbacea* and *Cerastium alpinum* be met with; the first-mentioned plant occurs most frequently. Here and there partially dried-up water courses and river-beds are found which are filled during the thaws of spring; and pools and small lakes are also occasionally met with hidden away in the low-lying ground between the ridges. In the immediate neighbourhood of the Jökulls,

where numerous glacier-rivers branch out upon the plateau, there are flats of rolled gravel and clay which are sometimes so steeped in water from the melting glaciers that they cannot be traversed.

On the interior plateau large areas (about 6500 square km.) are occupied by lava-streams — usually sheet-lava, with intervening tracts of slaggy lava. These lava-deserts are very poor in plant-life, and in the most highly-situated districts, they are almost entirely destitute of vegetation. Water is also very scarce, as the rain-water and the melting snow from the snow-drifts penetrate into the lava and do not reappear until far away as springs. The surface of these deserts consists of a hard, stiffened stony mass without a vestige of soil-covering, the hollows often filled with volcanic ashes and blown sand. The vegetation upon the lava-streams differs greatly on the plateau from what is found in the low-lying district, even if the lava-streams are of the same age; in the latter locality the oldest post-glacial lava-streams are often covered by a thick layer of soil, supporting heather-moors and coppice-woods; while on the plateau, lavas of the same age are quite bare. From Trölladyngja, a volcano in Odádahraun, an enormous lava-stream (Frambruni), 110 km. in length, has flowed down through Bárdardalur to Ullarfoss. Up at the volcano itself the lava, to a height of 1000 metres above sea-level, is entirely destitute of vegetation; lower down from Dyngjufjöll to Bárdardalur (800—200 metres), the vegetation becomes denser each step. The blown sand which has accumulated in the low-lying tracts, is here and there covered with lyme grass, which is soon followed by dwarf willows and heather. Down in Bárdardalur (160—100 metres) the lava is entirely covered with greensward and river-gravel so that only a few lava-peaks protrude. Near Lunda-brekka a rather thick layer of peat is formed on the surface of the lava; otherwise the large lava-waste of Odádahraun (600—1200 metres) is almost destitute of plant-growth. The few plants which occur are especially met with where hollows in the low-lying tracts are filled with blown sand; most frequently some tufts of *Elymus arenarius* can be seen, and here and there a few specimens of *Silenë maritima*, *Cerastium alpinum* and *Armeria maritima*. In places where the mountain streams from Dyngjufjöll have carried down a little clay, soil-formation has taken place to a small extent and extremely small specimens of *Salix herbacea* and *Polygonum viviparum* exist there. Lichens, which occur so frequently on low-lying lava-streams, are very rarely met with on Odádahraun, so the lava-surface is usually

quite destitute of covering; on the other hand, on lava-streams near Mývatn (above 300 metres above sea-level) lichens are very frequent. There, many species of phanerogams have also made their appearance, and both there and in Kelduhverfi the lava is often found to be covered by a thick carpet of moss. On Reykjanes scores of square km. of lava are entirely hidden beneath a soft greyish carpet of *Grimmias*.

Between Jökulsá á Fjöllum and Jökulsá á Brú, and between Kaldakvist and Skaftá, more recent tuffs appear upon the surface of very considerable tracts of the plateau, not covered by ice-striated dolerite-lavas or by modern, basaltic lavas. Where this tuff does not appear as bare peaks or steep mountain-chains, the surface is covered by lava-gravel disintegrated from the breccia, or else it is covered by blown sand, which is widely distributed, not only on the interior plateau but also in the lowlands. Blown sand is of varied quality and origin. It may be coarse or finer; it is sometimes so fine that it penetrates everywhere. During violent storms in sandy districts the fine dust is carried to the most remote quarters of the island and is deposited as a fine layer all over the surface: it even falls on vessels in mid-Atlantic. But naturally most dust falls in districts bordering on the tuff-belt or situated in it, as the dust chiefly originates from the tuff. The atmosphere in distant regions is often yellowish-brown because of the fine dust suspended in the air, and this dust-cloud is known in Iceland as "mistur." This tuff-dust has played a very important part in the formation of the Icelandic soil and subsoil, and it can be demonstrated almost everywhere. In the blown-sand districts proper, and in the neighbouring regions, where also larger particles of stone are put into motion, wind-blown sand has a great mechanical influence and is a mighty geological factor; its denudating effect upon the tuff mountains has been very great. Harder rocks are also affected by the sand; dolerites acquire a dull polish with irregular depressions, striations and furrows, while basalt is likewise sand-polished though to a less extent. Tuff and breccia mountains are always more highly disintegrated on the windward side, and the isolated fragments of basalt embedded in the breccia project further from the ground-mass on that side than to leeward. When the wind is stormy, great masses of blown sand are constantly driven through the narrow valleys, which occur between the numerous sharp tuff-ridges east of Túngná, so that no vegetation can thrive there; only here and



there upon the highest ridges and peaks, which cannot be reached by the coarser grains of the drifting sand, are seen small patches of soil supporting mosses and a few phanerogams.

In Iceland blown sand consists almost invariably of decomposed volcanic rocks; quartz-sand does not occur in Iceland. The most common blown sand is palagonite-dust usually of a yellowish-brown colour, which when examined microscopically, is seen to consist of glass-particles, tachylite, palagonite, plagioclase, augite and various



Fig. 15. Móhella in Króksdalur, not far from Sandmúladalssá. (Phot. Heinrich Erkes.)

finely decomposed zeolitic alteration-products. Volcanic ashes of recent date often occur as blown sand especially in the interior of the lava-wastes; they are heavier and less mobile, consequently, they are not dispersed in quantities beyond the volcanic districts. In the neighbourhood of the great glacier-bearing mountains, considerable tracts of level land are often covered with glacial clay, which when dried, crumbles into dust and drifts beyond the nearer surroundings. Around Dyngjufjöll, especially south-east of Askja, large areas are covered with blown sand, consisting of liparitic pumice-dust which all dates from the eruption of 1875. Moreover, stretches of blown sand consisting of decomposed mussel shells, i. e. calcareous dust, occur here and there along the coast of the north-western peninsula.



Owing to the variability of the wind-conditions, the dunes in the blown-sand districts are usually small and irregular in form; they are rarely higher than 3—4 metres, usually much less, and they are bound together by lyme grass and a few creeping dwarf willows. Sandy levels with low waves of sand are of general occurrence, and when moisture comes into play, the surface is cracked into numerous polygonal cakes by the action of desiccation or frost. The cracks are filled with drifted sand, so that the surface resembles a kind of mosaic.



Fig. 16. Soil torn up by the wind. Large tracts in Landsveit are occupied by these loess-like formations. Here several square miles of land, which were formerly wood-covered, are torn up by the north-east wind. The district of Landsveit, west of Hekla. (Phot. Th. Thoroddsen.)

In tuff districts proper older and younger æolian formations are the thickest and most widely distributed, and often alternate with volcanic and glacial formations; but the tuff-dust is also carried to the basalt districts, where they initiate the formation of the loess-like layers known in Iceland as “móhella.” Smaller layers of “móhella” occur everywhere in valleys and lowlands alternating with older and more recent glacial formations, with peat and lava-streams, but they decrease in thickness the further they are away from the large stretches of blown sand in the tuff districts. “Móhella” usually resembles a fine, easily crumbled, yellowish-brown or grey tuff, which is often traversed by stems of plants and red tuff-tubes which have been formed around the decayed stems; they

often alternate with layers of wind-polished stones, gravel, scoriæ or pumice, sometimes with clay. Where the blown sand is continuously moving, no vegetation can thrive, but when the fine dust and sand has blown away as far down as to the coarse gravel, Icelanders say that the sand is "örfoka," i. e. it cannot drift any longer (see Fig. 14). Then plants are again able to take root and new soil is gradually formed — until that also is blown away. The phenomenon of alternating periods of sand-drift and of vegetation, which has lasted through centuries, is nowhere so distinctly traceable as in Rangárvellir. Here the substratum is exclusively formed by "móhella," the thickness of which is unknown, but it must be considerable, probably 100 metres or more. Here the lowland plain abuts on the lava-fields of Hekla, whence quantities of volcanic ashes are blown down into the cultivated land. The lowland plain is intersected by deep, branching valleys, which are usually dry, but during the thaws of winter and spring large quantities of water have an outlet through these channels. From the plain a series of small terraces leads down to the bottom of these valleys, which often consists of a grass-covered, level stretch of land. The valley-sides offer favourable opportunities for studying the composition of the móhella: fine bluish-grey layers of sand alternate with reddish sand-layers penetrated by compounds of iron, and the embedded stones of varying sizes bear testimony to the strong erosive action of blown sand. In some layers soil and remains of plants occur, also clay-tubes formed around haulms of grasses. Here and there layers of pumice and scoriæ are also seen. No inhabited district at the present time is so exposed to being attacked and overwhelmed by blown sand as Landsveit in the southern lowlands. Here, during the nineteenth century, large stretches of grassland and many farmsteads were overwhelmed by drifting sand, especially in the years 1836 and 1880—1881. The substratum consists of old lava which formerly had a covering of móhella and greensward, now to a great extent torn up and destroyed by the masses of blown sand from the north-east. Sand storms cause deep channels and furrows in the soil, which constantly enlarge and by combining with others, gradually destroy the entire layer of soil, so that only a few massive fragments of móhella with hollowed sides and covered with greensward traversed by the fibres of plants, are left behind until they also succumb to the universal destruction. In large stretches of this district all greensward and soil have been torn off down to the naked lava-rock.

From here proceed broad, ramified channels containing blown sand, which are continued and widened, and which constantly encroach on the remaining piece of grassland. The north-eastern part of this district was formerly covered with heather and coppice wood, which the inhabitants, with incomprehensible lack of foresight, destroyed and used for fuel. Skarðsfjall, which stands in the centre of Land-sveit, has protected the areas situated in its shelter towards the south-west. Some streams have also checked the advance of the drifting sand and have thus acted as a protection. Most of the blown sand which in various ways devastates the cultivated districts, originates from the wastes of the plateau. There is indeed enough and to spare of it, at least 3—4 thousand square km. of the interior being covered by blown sand of various thickness. On the plateau the blown-sand tracts appear rarely or never to become "örfoka," therefore they are almost always quite bare of vegetation with the exception of the scattered tufts of lyme grass and a few small wil-lows in more favourable localities. In the elevated districts, the surface of which we have been describing, many plants cannot be expected to thrive. As we shall have occasion to mention later on, the highest part of the interior of Iceland, at a height of 650—1000 metres, is a waste extremely poor in plant-life.

The lowlands, as mentioned above, cover only a very small area ( $\frac{1}{15}$ ) of the entire surface of Iceland; and a considerable part of this small area consists moreover of barren soil, of lava-streams, of stony rocks and ridges poor in plant-life, and of glacial and blown sand. Therefore the area which may properly be regarded as densely covered with plants, is very small compared with the entire area of the country, and with the present method of cultivation it could scarcely maintain the rural population if the mountains and parts of the plateau could not be utilized as pastures for sheep during the summer. The extent of plant-distribution differs, however, greatly in the different parts of the lowlands. While some of the districts are almost entirely or for the greater part covered by a dense vegetation of grass, sedges, heather or coppice-wood, as Ölfus, Flói, Skeið, Landeyjar, Mýrdalur, etc., great parts of other inhabited districts have not even half of their area grass-covered. Several inhabited areas in Skaftafellssýsla, Mulasýslur and Thingeyjarsýslur contain very large tracts of rocky flats, poor in plant-life, lava-streams, sandy wastes, etc.; and in some districts only a very small fraction of the surface is of any use for the sheep- and

cattle-rearing of the rural population. The peninsula of Reykjanes, which is of no great elevation, more than half of its surface being below 100 metres, and which has a comparatively mild climate with a considerable rainfall, is, however, so poor in plant-life, that only 4 per cent of the area is grass-covered. The area bounded on the west by Lágaskarð and on the south by Hafnarfjörður is about 1635 square km., but of this only at most 69 km. is occupied by grassland. The greater part of the area of the peninsula of Reykjanes is covered by more recent lava-streams, and has a scanty vegetation; the inhabitants along the coast maintain themselves chiefly by fishing.

As it has already been remarked, the surface of the lowlands varies in character. It usually consists of loose masses, but sometimes also of solid rock which projects here and there through the more recent formations and the older and more recent lava-streams, as crests, ridges and hills. As mentioned above, in South Iceland large areas (2000—3000 square km.) are covered with glacial and volcanic sand, through which branching glacier-rivers flow. Although these sandy tracts originate mainly from river-gravel and sand, other constituents are also found intermixed in them, for instance tuff-dust, and volcanic scorix and ashes, where active volcanoes occur in the neighbourhood. On Mýrdalssandur volcanic slags and ashes predominate. River-gravel and glacial clay occur only upon the surface of changing river-beds. The vast Skeiðarársandur, on the other hand, is formed almost exclusively of rolled glacial-gravel mingled with fine sand and clay, which increases in amount the nearer the coast is approached. The various sandy tracts differ naturally somewhat as regards the quality of the material and the size of the grains, etc. Old lava-streams, also, extend over large areas of the lowlands; they are usually covered with soil which supports a luxuriant vegetation with heather-moors, coppice-woods and grasslands. In thickly inhabited districts such as Flói and Skeið, the substratum is of lava, and in the former district it is marshy, as it lies so low (at the level of the sea), that the water cannot drain off. Flói is jammed in between two river-deltas so that the rain-water cannot be drained away owing to the pressure of the bottom water, and in rainy years this district suffers greatly from water which has no outlet, so that the ground is quite boggy. The underlying lava protrudes from every hill and the soil is mixed with lava-fragments. The lowland tract of Flói gradually merges into the district of Skeið which



is situated upon the same lava-stream, but as the level above the sea is somewhat higher, the water most frequently penetrates into the lava, and the soil is sandy, hard and dry and covered with a good and vigorous growth of grass. The sedges disappear or retreat to small patches where the local conditions allow the accumulation of a greater amount of moisture. The thicker soil-layers upon the lava-streams, usually originate from tuff-dust (*móhella*), which has been carried thither and has gradually filled up all the depressions, and from glacial clay deposited by rivers. Several lava-streams with a thinner layer of soil support coppice woods — e. g. on Thingvallahraun, and Hvitárhraun — and heather, as on Reykjaheiði near Kelduhverfi, and others. In the lowlands the quantity of the plant-growth upon the lava-streams is closely connected with their age, and by the end of a century, a number of species has already settled down on a lava-stream, as may easily be seen upon the Skaftá-lavas of 1783 and the Leirhnúk-lavas of 1724—30; on the other hand, the lava-streams of Sveinagjá, which date from 1875, are still very poor in phanerogams.

In the most thickly inhabited districts the substratum of the soil generally consists of older and more recent glacial and alluvial formations, very often in connection with "*móhella*," volcanic ashes and lava-gravel. In the lowlands, which were covered by the sea at the close of the Glacial period, marine sand and clay layers are most frequently found immediately upon the basal rock. The clay, which was deposited by the glacial rivers of the Ice Age, often occurs in layers of considerable thickness; it is most frequently bluish-grey in colour and turns blackish-blue on being wetted; it is very tough and dense, and can often become rather hard. The clay contains a very insignificant amount of carbonate of lime, usually only 0.1—0.2 per cent, while the Danish Yoldia-clay, according to Johnstrup, contains 5—15 per cent of carbonate of lime. Along the rivers the banks of clay may often be traced for several kilometres without any disturbance being observed in the position of the layers, which is extremely regular and nearly always horizontal. The thickness of the clay-formations varies greatly; in the most highly situated parts of the lowland area and in the valleys, it is sometimes as much as 20—30 metres, further down from 5 to 15 metres. The thickness diminishes the nearer the coast is approached; but it may vary greatly. The clay occurs not only where rivers cut through, but also as a substratum below morasses. Marine sand



often occurs above the clay, and then more recent river-deposits, alternating with móhella, volcanic gravel, etc. Here and there, these formations are exposed at the surface and form an almost barren gravelly flat (melar), which, far into spring, is quite slushy, owing to the melting snow, which cannot drain away on account of the sub-surface ice and the clayey subsoil. In the eastern part of the southern lowland tract, under the boggy ground, occur enormous river-deposits (Landeyjar) — delta formations from Markarfljót and other rivers. But higher up, where the soil is drier (Rangárvellir), the subsoil is composed of thick móhella-formations; nearer to the sea occur fine sand and downs.

In several districts in the lowlands there are a great many rocky ridges (holt), which protrude through the morasses and grass-land. They vary in nature according to the character of the underlying rock, and generally consist of basalt or dolerite, rarely of palagonite-breccia. These ridges usually bear clear evidence of the action of the glaciers during the Ice Age. They are highly ice-striated and often have two distinct sides, one bearing traces of having been exposed to the direct force of the ice, while the leeward side is comparatively destitute of such marks. Their external form is sometimes dependent upon the direction of the inclination of the basalt-layers. In some places (Mýrar and Breidifjörður) they originate from fragments of a deeply sunk basal rock. The surface is usually stony, with solid rocks, larger loose stones, and smaller gravel; sometimes a great many erratic blocks are scattered upon the ridges. As regards plant-growth, these ridges should be characterized as rocky flats more or less covered with vegetation, and protruding like small islands above the grass-covered, usually boggy level lands. In several places the ridges, in olden times, have been clothed with coppice woods, but it is centuries since the coppice has been destroyed by sheep and goats. Such ridges are found scattered over a great part of the island in the lowlands and valleys, and often impart a characteristic feature to the landscape. The farm-buildings are often built upon them. In the low-lying marshy land of Mýrar, at the edge of Faxaflói, they occur scattered in hundreds in the bogs, and in the southern lowland district they are frequent in the eastern part of Flói and the upper part of Holt, while elsewhere large stretches of this lowland area are completely flat. In other districts they are so large that they are most properly described as small mountains (fell, hálsar). In the valleys the old moraines are often trans-

formed by the rivers, and converted into terraces, which form the substratum of bogs and grassland. The glacial moraine-gravel often extends far up the mountain-sides and forms here a substratum for soil and plant-growth. In other places in the valleys are steep rock-faces, stony slopes, heaps of large fragments of rock (urð), and the conical heaps of finer and coarser gravel brought down by the mountain-streams, which all help to give variety to the plant-formations. While basalt-mountains are slightly and slowly disintegrated, tuff-mountains are extremely liable to disintegration, hence the products of the latter, combined with the action of wind, glaciers and rivers, play a more important part. The contribution of the basalt towards soil-formation dates mainly from the Glacial period. As we have seen from the above, the substrata which support plant-growth are (1) firm ground, having a rocky base (basalt, liparite, breccia and lava); (2) loose soil, consisting of moraines, river-gravel, sand, clay, blown sand, volcanic ashes and tuff-dust (móhella); and (3) the products of the plants themselves: boggy soil composed of peat and humus.

The character of the subsoil below the humus-layer and the plant-covering is consequently in close relation to the chemical and mineralogical composition of the underlying rock. Over the greater part of Iceland the inorganic soil consists of decomposed basaltic rocks, the main mineralogical constituents of which are plagioclase (especially lime-felspars) and augite, but magnetite and olivine also occur, often in great quantities, and apatite and a small quantity of titanite. The chemical composition of the Icelandic basalts is rather uniform. On an average they contain 43—53 % of silica, 11—18 % of alumina, 11—22 % of iron ( $\text{FeO}$  and  $\text{Fe}_2\text{O}_3$ ), 8—13 % of lime, 2—9 % of magnesia, 0.2—2 % of potash and 1—4 % of soda. Because anorthite, of the plagioclases, is very largely distributed in the Icelandic rocks, not only in the basalt, but also in the recent lavas and tuffs, these Icelandic rocks often contain a comparatively small amount of silica and a very considerable amount of lime and also alumina. The reason why the Icelandic soil is nevertheless poor in carbonate of lime may be found in the fact that the lime can only with difficulty be separated from its siliceous compounds, and because in the whole of the island, no sedimentary calcareous rocks are found, though such are of common occurrence in other countries. In districts where sulphurous acids sent out from fumaroles have affected the rocks, as is common in tuff-districts,

calcium sulphate (gypsum) is very common in the soil. The Icelandic basalts have not been investigated with regard to the amount of apatite contained in them, but judging from the abundance of phosphoric acid which often occurs in the waters of the large rivers, it must, in some places, be very considerable. In the districts where liparite is the main rock, the soil has not yet been investigated, but it must vary somewhat, on account of the varying composition of the rock, which contains much larger amounts of silica (65—78 %), potash (2—4 %), and soda (3—6 %) than the basalts. For the rest, the Icelandic liparites show evidence of their connection with the basalt-area in which they occur, by the fact that almost all of them are soda-liparites.

From Iceland there are as yet only a few soil-analyses to hand, and from a few districts only.<sup>1</sup> In calcined samples of fine soil from dry grasslands the main mass consisted of silica (37—48 %), alumina and peroxide of iron (38—50 %), while lime, magnesia, alkalies, present as silicates and other compounds, were found in quantities of from 7 to 14 %. The amount of carbonate of lime was but small, and varied from 0.5 to 1.7 %; in home-fields most frequently 1.5—1.7 %. On the other hand, the amount of phosphoric acid was larger (0.3—0.4 %) than in ordinary Danish soil. The soil samples were rich in humus and contained an unusually large amount of nitrogen considering the amount of humus — from 7 % to as much as 24 %. The amount of humus and also of iron compounds is larger than in ordinary Danish soil. Under unfavourable conditions of humidity the abundance of the organic substance found in the soil constitutes a danger, on account of the formation of protoxide of iron; and climatic conditions make the chemical changes in the materials of the Icelandic soil difficult and slow in wet tracts. The amount of the inorganic substances in the sand-samples gives a correct idea of the chemical composition of the solid basaltic rock.

Some analyses have been made of Icelandic plants. Firstly, of Icelandic hay, both hay from home-fields (tun; see Fig. 17) and hay from dry and from wet meadows. The analyses show that the Icelandic hay resembles mountain hay from the Alps. It contains a larger amount of fat than does the Danish hay; less cellulose;

<sup>1</sup> Analyses of Icelandic soil are found in P. Feilberg: *Bemærkninger om Jordbund og Klima paa Island* (Tidsskrift for Landøkonomi, 1881) and by A. Torfason in *Búnaðarrit*, Reykjavík, XX (1906), pp. 173—184; XXIII (1909), pp. 52—54. Also, in the recently published work by M. Gruner: *Die Bodenkultur Islands*, Berlin, 1912.

and a larger amount of ash.<sup>1</sup> Afterwards, many different species of plants were analyzed and compared with Swedish plants and the main result arrived at was very similar.<sup>2</sup> P. Feilberg writes: "Iceland is the land of the Cyperaceæ and of the coarser species of grass, but the sheep and the cattle which through generations have accustomed themselves to this coarse food, thrive well on it. The chemical contents of the fodder show that this is also possible, nor is there any reason why it should be otherwise."

In a damp and cold climate such as the Icelandic, the chemical changes in the material of the soil take place more slowly than the formation of vegetable matter, which accumulates and absorbs water where this is copiously present; thus the entrance of air is prevented, and heat is not generated. These circumstances give rise to the production of acid, boggy humus as in other northern countries with a cold and damp climate. Considerable areas in Iceland are covered with boggy soil, and there are also the very best conditions for the formation of peat and bogs. In some parts of the lowlands there are vast extents of bogs and swamps, as e. g. in Mýrar and Andakíll at the head of Faxaflói, and in Flói, Ölfus, Holt, etc. in the southern lowland tract; while larger and smaller swampy areas are found almost everywhere. In the lower-lying parts of the plateau there are also wide stretches of boggy land, e. g. Tvídægri, north-east of Langjökull; Miklumýrar, north of Hreppar, and many other places. In the majority of the districts the area of wet grassland, covered with Cyperaceæ and mosses, exceeds by far that of the dry grassland, but unfortunately as yet no measurements are to hand as regards the extent of the bogs.<sup>3</sup>

There are considerable peat-formations in the Icelandic bogs, but their thickness, distribution, plant-remains, etc. have not yet been investigated. In Skaftafellssýssel where glacier-rivers and volcanic

<sup>1</sup> Josep J. Björnsson: Um heygæði (Thjóðólfur, 1886, No. 40). P. Feilberg: Græsbrug paa Island, Kbhavn., 1897, pp. 14—17.

<sup>2</sup> St. Stefánsson and H. G. Söderbaum: Isländska foder- och betesväxter (Meddelanden från kgl. Landbruks-Akademiens experimentalfält. Nos. 74 og 83, Stockholm, 1902 and 1904). Also in Búnaðarrit, XVI. 1902, pp. 179—196; XVII, 1903, pp. 25—66; XXIV, 1910, pp. 1—48.

<sup>3</sup> M. Gruner's "Die Bodenkultur Islands," Berlin, 1912, came to my notice after I wrote the above; in it he estimates the entire bog area of Iceland at 10,000 square km. or about 10 % of the entire area of the island. According to this, as regards the extent of its bog area, Iceland is reckoned to be third among the Scandinavian countries (Finland 27.2 %, Sweden 12.6 %, Iceland 10 %, Denmark 5 % and Norway 3.7 %).



eruptions have constantly been influencing the soil-formation, peat is rare. In the peat there often occur quantities of stems, roots and branches of *Betula odorata*, and Francis J. Lewis<sup>1</sup> has found remains of *Betula verrucosa* in peat-bogs in South Iceland. Even in districts where birch-copses no longer thrive, as e. g. on Hornstrandir north of Jökulfirðir, birch-stems are found in the peat bogs. The Icelandic peat is largely utilized as fuel, and as regards its fuel-value it compares favourably with peat from other countries,<sup>2</sup> only the amount of ash is rather considerable, especially in peat from South Iceland, perhaps on account of the presence of volcanic ashes and blown sand. In the Icelandic peat-bogs there usually occur several, or a few, bands of volcanic ash of various thickness, usually basaltic ashes, but yellowish liparitic pumice-ash occurs also. In districts situated in the neighbourhood of active volcanoes the ash-bands in the bogs are very numerous. Bog iron-ore occurs also in the Icelandic bogs; in some places in rather considerable quantities. In olden times it was much used by the inhabitants, and for the smelting of the iron many coppice woods were destroyed. Parts of various boggy stretches — wet meadows — have great economic importance, and the hay (uthey) is largely used as fodder for sheep and cattle, especially as winter fodder for horses and sheep; the best part of it, only, is used for the cows, which live mainly upon hay from the home-fields (tun-hay). In 1910 about 14,300 tons (each ton 1000 kg.) of this uthey were harvested. Of the largest and most productive meadows of this kind may be mentioned Hvanneyri in the district of Borgarfjörð, Forin in Ölfus and Safamýri in Holt. At the mouths of various large glacier-rivers are large and very fertile stretches of meadow-land, which either constantly or else at times are flooded by glacier water, e. g. in Lón in East Iceland, at Hvanneyri in Borgarfjörð, and in several other places where a kind of marsh is formed by the deposited glacier-clay which contains fertilizing substances; in such places the river-water is no longer very cold, and has a very slight current or none at all. In water from Icelandic rivers the following substances of use for plant-food were found: the figures given are those for five million pounds of water (one pound = half kg.).<sup>3</sup>

<sup>1</sup> F. J. Lewis: Stratification of Peat Deposits in Iceland (Transactions of the Royal Society of Edinburgh, Vol. 47, Part IV (No. 26). Edinburgh, 1911, pp. 827—831).

<sup>2</sup> Analyses of Icelandic peat by A. Torfason are found in Eimreidin, XI (1905), pp. 40—41, and in Búnaðarrit, XX (1906), pp. 116—119.

<sup>3</sup> The analyses are found in P. Feilberg: Græsbrug paa Island, 1897, p. 22;



	1 Danish Streams	2 Hörgá	3 Eyjafjardará	4 Hvítá (Borgarfjörð)	5 Laxá from Mývatn	6 Hvítá (Arnessýsla)	7 Tjörðará	8 Tjörðará; during the thaw of 1898
Nitrogen . . . .	15-20	1.37	4.65	1.35	110.00	4.9-14.12	4.5- 6.5	3
Potash . . . . .	10-15	13.50	11.50	11.00	15.50	12.5-17.5	11.0-15.5	140
Phosph. acid.	0.6-1.0	1.05	5.00	4.35	35.00	1.5- 3.5	5.6-19.5	157
Lime . . . . .	100-700	33.02	35.00	41.50	55.00	21-37	49-82	46

In several places river-water is utilized for irrigation, and irrigated meadow-lands were calculated to cover an area of 28.4 square kilometres in 1909.

The only cultivated soil in Iceland is that of home-fields (tun) around the farm-buildings. These home-fields are manured and levelled, but generally are not ploughed. The extent of the cultivated areas (tunes) of the whole of Iceland was in 1909 calculated to be 187.8 square kilometres; to this should be added 2.8 sq. km. for the cabbage and potato plots. There are often numerous knolls in the tunes, which render haymaking very difficult (Fig. 17). Therefore the improvement of the soil consists in the levelling of these knolls, which, however, reappear in several places after a time. The nature of the tunes and the quality of the soil naturally differ greatly according to cultivation and situation. The grass (tada) from the tunes consists mainly of Gramineæ, and, as already mentioned, is used as winter fodder for the cows. In 1910, 5145 tons of tun-hay (tada) were cut. Outside the home-fields there is also a great deal of dry grassland (harðvelli) covered with Gramineæ, which is chiefly used as pasture-land for sheep and cattle. In the soil of the tunes and the dry grassland a larger quantity of lime and phosphoric acid is usually found than in that of the wet meadow-tracts.<sup>1</sup>

As in other arctic and subarctic regions, "soil-flows" (Solifluktion) are a common phenomenon in Iceland, and they exercise, especially in mountainous regions, no slight influence upon the soil and plant-growth. The upper layer of the soil upon slopes and

and in Búnaðarrit, XXII, 1908, pp. 265 and 266. No. 1 is by Feilberg and Westermann, Nos. 2, 3, 4, 5 and 8 by Detlefsen and Meyer; Nos. 6 and 7 by A. Torfason. Nos. 5 and 8 appear somewhat doubtful.

<sup>1</sup> P. Feilberg in Tidsskrift for Landøkonomi, 1881, pp. 8-12.

mountain-sides is saturated with water from melting snow during spring, and slides slowly downwards; very often gravel and clay is by this arranged in bands down the slopes. Below large snow-drifts which persist till far into summer, or during the whole of summer, there is always water which soaks into the soil, and upon many mountain-sides, slow-flowing mud-streams are formed, which in shape and movement recall small glaciers. In other places the flowing



Fig. 17. An old Tun. Kjós near Reykjavík. (Phot. A. Hesselbo.)

soil forms small terraces, which are partially transformed into rows of knolls overgrown with plants. Sometimes the soil is loosened from the solid rock, or slides upon the ice of the subsoil; sometimes clayey streams flow down into depressions and valleys, and occasionally fragments of greensward, which had been resting upon a saturated substratum of sand and clay, are loosened. Frequently it can also be seen how water, flowing upon the ice of the subsoil down the slope, undermines the soil so that large pieces of greensward are put into motion, give way, and are torn asunder. It may also happen, where there is a thick layer of loose soil, that the

downward-flowing water, during thaw, tunnels below the ice-layer and forms subterranean channels, causing the upper layer to collapse and fall down into these hollows. In this way, after the volcanic eruptions of Askja in 1875, great damage was done to the soil on Jökuldalur; its enormous moraine-terraces were covered with pumice-gravel which froze into a thick layer that melted but slowly, because the white, glistening gravel reflected the rays of the sun; below this layer, the water dug out channels, 20—30 metres deep, through earth, sand and gravel, and caused catastrophes such as that mentioned above.

In this connection may be mentioned the influence often exerted upon the soil by the numerous avalanches and rock-slips of different kinds, and the very slow, creeping movement which may be observed in connection with gravel, stones and rocky blocks upon the mountain sides which, in the course of years, may become of very great morphological importance. During earthquakes it may happen that mountain-sides clad with grass and coppice are suddenly denuded of their surface soil, which slides down into the lowland plain. During the earthquake of 1896 a piece of swampy soil, 10,000 sq. metres in area and 2—3 metres thick, at Thjórsá in the neighbourhood of Krókur, thus slid down, being thrown into wavy folds and hummocks, although the slope of the ground was only 1—2°. The mountain of Skarðsfjall, which rises 227 metres above the plain, had, before the earthquake, a thick coating of soil, and was grass-covered to its verge; but after the earthquake it resembled a fruit which has been peeled. Thirteen landslips descended on the western side, leaving behind them large surface depressions, and strewing below mighty mounds of soil, clay, gravel and stones together with larger and smaller fragments of torn greensward. These landslips must, in the course of time, have had an enormous influence upon the soil and the plant-growth of many districts where earthquakes are very frequent. All over the island are often seen, along the mountain-sides, marks of ancient huge earth- and rock-slips that could only have occurred during earthquakes.

Level tracts with their surfaces cracked into polygonal cakes (rudemarks) are extremely common in Iceland, and fine specimens of such may be seen as, for instance, in the neighbouring districts of Reykjavík. They have a peculiar effect upon plant-distribution on the rocky flat. "Rudemarks" are usually formed only on flat land where the soil consists of gravelly clay — especially clay inter-

mixed with a large quantity of tuff-dust (*móhella*). The surface is divided into squares or more or less regularly formed polygons, by bands of small stones or gravel, while the clay of the interior of the squares or polygons is destitute of stones. The surface resembles a net — the meshes of which are formed by irregular bands of gravel. Usually it is only the gravel which supports plant-growth; there the plants can find shelter between the stones, while the middle of the clay-cakes is too wet for plant-growth. But when the “rudemark” becomes drier, vegetation may gradually extend over the

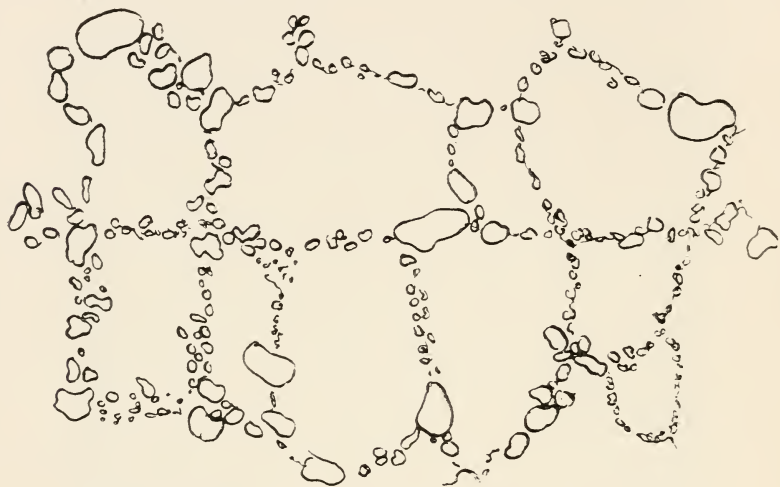


Fig. 18. Portion of a “rudemark” in the neighbourhood of Reykjavík.  
showing the position of the stone and gravel bands. (Drawn by Th. Thoroddsen.)

cakes of clay, first forming a scattered growth upon them and ultimately soil and a plant-carpet, especially when tuff-dust and drifted soil have settled on the surface. The polygonal cakes vary greatly in form and size, but generally they have a diameter of only  $\frac{1}{2}$ —1 metre. The knolls (*púfa*, pl. *púfur*; see Fig. 17), which play such an important part with reference to Icelandic vegetation and agriculture, stand in close genetic relation to the “rudemarks” and we will therefore try to give an account of the way in which they both have probably originated, but questions bearing on this point require to be elucidated by the experimental investigations of persons living on the spot. My investigations in Iceland have confirmed me in my opinion that the Icelandic *púfur* — as already mentioned — stand in a close genetic relation to the “rudemarks” and that sub-surface ice is an essential condition for the formation of both;



where for some reason or other no ice-layer is formed in the ground, neither "rudemarks" nor knolls seem to occur.

The depth at which this ice is present in spring differs greatly in the different parts of the island, and — according to the weather — in the different years. In the northernmost districts this ice may remain throughout the summer for years during cold and damp periods. As a rule, in the first half of June, frozen ground is met with at a depth of 1—1½ metres over the greater part of the island; on the plateau a thicker or thinner layer of this sub-surface ice is no doubt always present throughout the summer, and there, in several places, it gives rise to the formation of swamps, bogs and lakes, as the melting snow and ice cannot drain off. In some districts with very warm ground, where hot springs or other secondary effects of volcanoes occur, the ground is never frozen.

As is well-known clay and clay-soil develop, by contraction, numerous intersecting clefts; such cracks are also formed during winter by the action of frost, and in severe winters loud cracks are constantly being heard, announcing the rending of the ground. The surface layer of soil is therefore traversed by a network of numerous rents and cracks which divide the clay-soil into irregular fragments or a number of prisms. On closer investigation these cracks are not only found to occur on gravelly and clayey flats, poor in plants, but also in the clay-humus of the home-fields; some of them are as fine as hairs, others have a breadth of 2—3 cm. Both these factors, the sub-surface ice and the cracks in the ground, are necessary to the formation of "rudemarks" and knolls, and to these should be added two other very important factors, viz. frost and unequal surface-evaporation.

When, in spring, the snow melts on the cracked and netted surface of a flat consisting either of clayey gravel or of plant-covered clay-soil, and the flat itself thaws at the surface, the water percolates through the ground and the cracks, but cannot escape on account of the sub-surface ice so that the entire layer of soil becomes saturated with water. Where the flat consists exclusively of sand and gravel, without any mixture of clay, the entire soil-layer is evenly saturated and the surface of the water can sometimes rise to a level with that of the ground. Evaporation then takes place evenly over the entire surface, and when the sub-surface ice melts, the surface-water drains away or evaporates, and nothing further happens. But on a clayey gravel-flat intersected by a network of



cracks, the circumstances are somewhat different. During spring the ground is partially thawed; it freezes in the night and thaws during the day. The sub-surface ice forms a downward limit which does not permit the water to drain away, and uniform circulation and evaporation at the surface are prevented in a "rudemark" by ice-formation in the many cracks, originally full of water, which together with the sub-surface ice as a base form a vascular- or cell-system over the entire flat, and this system lasts at least for some time. The water from the melting snow and ice on the surface collects mainly in the cracks and depressions, where it freezes during the night; this is best observed on a knolly flat, which during the thaw of spring produces an entire network of small water-canals. The water cannot penetrate downwards on account of the ice in the cracks or, if they should be free from ice, it will yet remain for a long time in them, for as the water-layer is thicker there than upon the polygonal cakes, the evaporation is slower. The heating of the sun and consequent evaporation of water is therefore greater on the cakes, so that the wet from below, from the slowly thawing parts of the ground and the ice of the subsoil is drawn up into the centre of the cakes. A clayey soil with particles of a certain size has great capillary power and can absorb water and draw it up in great quantities.<sup>1</sup> The power of absorption of the clay-soil is greatly increased when it is covered by soil, humus and plant remains. During spring, frost and thaw alternate constantly and daily. The "rudemark" freezes in the night, at least partially, and thaws in the morning; in the course of the day the water rises in the individual clay-prisms owing to the rapid evaporation from the surface, but in the night it freezes, expands and raises the central part of the cake. This occasions a constant wandering of the particles of the clay soil upwards into each clay-prism, and by the constant pressure exerted by the frozen soil throughout a long period, the heavier particles are sorted out, and as they are less mobile, they are left behind or pushed to the sides. This sorting-out of the coarser material is the most characteristic feature of the "rudemark." The enormous pressure due to the freezing process is well known. As will be mentioned again later on, in several places in the Iceland mountain-bogs there are opportunities of observing how the frozen

<sup>1</sup> The air contained in sandy clays in a dry condition may amount to 40 % of their volume, and by infiltration, as large a volume of water may replace the air. See A. G. Högbom in *Geol. Förhandl.*, Stockholm, 1905, XXVII. p. 22.

water inside the knolls can rupture a greensward, 10—20 cm. thick, and traversed with plant-roots. This pressure from below, repeated for years in a "rudemark," must gradually push and force the gravel aside so that it lodges at last in the cracks which, while they are filled with ice, form a kind of wall around each clay-prism. Thus the stones are placed in the neutral territory between the small centres of power, and form a boundary to each cake, the upper edge of which boundary appears upon the surface while the lower reaches down to the ice in the subsoil. Below the level of this ice the gravel is irregularly dispersed in the clay; it is regularly arranged only in the surface-layer above the ice. In the summer, when the soil has thawed and the sub-surface ice melted, the water drains off, and the "rudemark" dries. Everybody who has travelled in Iceland during spring knows what an enormous difference there is between the clayey gravel-flats in which the horses sink deep down while the ice of the subsoil still hinders the draining off of the water, and the same flats in summer when they are dry, so that horses can gallop across them. During summer the clay-polygons become somewhat depressed. Many of them are however slightly arched during the summer also and retain for a long time a considerable amount of wet in their interior. Clay which easily absorbs water and expands is well known to Swedish geologists<sup>1</sup> who call it "jäslera," and recently it has been connected with "rudemarks."<sup>2</sup> In the neighbourhood of Reykjavík (Melar) some well-defined "rudemarks" have developed in clay soil where a water-containing layer at a depth of about 1½ metres rests on a thick "móhella" through which water can penetrate only with difficulty, and which therefore freezes in winter into a plate of sub-surface ice. Where the ground consists of clayless sand no "rudemarks" are developed, nor where the subsoil is so porous that water cannot accumulate and form sub-surface ice proper.

In my opinion the knolls which are of such common occurrence in the home-fields of the farmsteads (see Fig. 17) are developed in a similar manner. These knolls are usually larger or smaller elevations of earth which occur together in numbers: the surface-layer consists of humus and plant-remains, but the interior is formed

<sup>1</sup> A. G. Högbom: Om s. k. jäslera och om villkoren för dets bildning (Geol. Fören. Förhandl., Stockholm, XXVII, 1905, pp. 19—36).

<sup>2</sup> E. Bergström: En märklig form af rutmark från barrskogsregionen i Lappland. Geol. Fören. Förh., XXXIV, 1912, pp. 339—340.

of the clay soil, which projects into them like a kernel and forms the main part of their volume. The knolls have usually a diameter of  $\frac{1}{2}$ —2 metres and a height of  $\frac{1}{4}$ — $\frac{1}{2}$  metre; sometimes they are somewhat smaller; or they may be larger. The form varies, but is usually oblong. When the knolls are large the channels (kargatthyfi) between are but narrow. The thicker soil-layer together with the greensward-covering and the vegetation, are intersected by a network of cracks similar to that in the "rudemarks." These cracks divide the ground into numerous pieces of various shapes which behave, as regards the sub-surface ice and the moisture, as the "rudemark." The knolls are dependent on the crack-systems of the substratum. In the knolls the ascending stream of clay and humus particles must be stronger than in the cakes of the rudemark as the greensward, rich in humus, has a very great capillary attraction and an enormous water-capacity — it can absorb water to the extent of 50—60 % of its volume; therefore during the evaporation from the surface it absorbs water vigorously, not only from the thawing ground below, but also laterally from the channels between the knolls filled with water during the spring thaw: in spring the greensward upon the smaller knolls is as saturated with water as a sponge. Bands of volcanic ashes, which were present in the ground or in the greensward before knoll-formation began, become bent upwards in curves according to the form of the knolls — a fact which, among others, is a proof of the local pressure from below in each knoll. In spring, during the melting of the snow, the channels between the knolls are often half filled with water which cannot escape, while the tops of the knolls are dry, sometimes even very dry owing to evaporation, so that the vegetation upon them is totally different from that upon the sides of the knoll. Sometimes large knolls have a kernel of ice far into the summer. The formation of knolls does great damage in the peasants' home-fields and great trouble is taken in levelling them, but they may reappear comparatively quickly if the ground is not thoroughly drained, so that the surface-water and the water from the melting ice of the subsoil are immediately carried away. In this connection it should be mentioned that where a snow-covering during spring protects the ground for a long time against the action of frost and thaw, no knolls are formed.

Knolls of the kind described above occur in thousands also in uncultivated grasslands with clayey móhella-soil, on heather moors and on grass "móar", and here, also exclusively upon somewhat flat

land<sup>1</sup> and in places where the water, for some reason or other, cannot drain off. Here the soil is usually much thinner than in the home-fields but nevertheless it has a very great power of absorption during the process of surface-evaporation; the greater part of these knolls consists of móhella-clay. On an entirely bare clay-flat no knolls are found, and the separate cakes in the „rudemark” rise but slightly in the middle during spring, but not until they are plant-covered and clad with greensward do they bulge and retain their convexity. On a closer investigation it is probable that several transitional forms will be found between “rudemarks” and knolly flats, but investigators have not as yet made this matter a subject for study. Where similar plant-formations (heather and “móar”) occur upon slopes or mountain sides upon which the water easily finds outlets, knolly flats are absent, and “rudemarks” are never found in such localities. Upon mountain-sides small eminences of various kinds may sometimes be observed which are due to underlying stones or ridged mud-flows, etc., but never “thufur” proper. Nowhere have I seen any indications of “rudemarks” or “thufur-marks” being at all connected with mud-flow phenomena.

On the plateau peculiar knolls of usually large size are found which the inhabitants of the different districts call “rústir,” “haugar” or “dys.” These knolls are, as a rule, of irregular, oblong form, and are bare of vegetation on the top, where they consist only of humus and clay. It can be seen that the ground has bulged and the knolls are cracked at the top. In some places there are evident proofs of this being the case: bands of the original soil are seen to lie upon the top of the knoll while the clay and gravel within have poured out of the cracks between the bands. In the neighbourhood of Ulfsvatn on Tvidægra, at a height of 460 metres above sea level, I investigated such knolls in 1898; they were 1—1½ metres in height, 15—20 metres in length and 8—10 metres in breadth. The sides were covered with heather, but *Cyperaceæ* grew in the intervening spaces. Similar knolls occur in several other places in the interior of Iceland, but only in one more place did I observe

<sup>1</sup> Dr. H. Jónsson describes a heather-covered “rudemark” where the cracks between the cakes were covered with *Grimmia hypnoides*, but the cakes themselves with *Calluna* and *Empetrum*. This peculiar vegetation — the brownish heather-vegetation divided into numerous polygons by the greyish moss-bands — occurred only upon level ground (Botanisk Tidsskrift, XXVII, 1905, pp. 43 and 44).



them to be as large as those at Ulfsvatn, viz. in East Iceland on the plateau south-east of Snæfell, at a height of 690 metres above sea-level. This was in 1894, but the inclemency of the weather prevented me from making a halt at the place. Here, also, several of the knolls had burst and discharged a large quantity of clay-soil. This form of knoll occurs especially at the edge of the bogs where the foot of the knoll stands in water during the melting of the snow: where the supply of water is too abundant these knolls do not occur. It is a fact peculiar to all knolls, both in the lowlands and on the plateau, that they consist of móhella-soil and humus intermixed with clay; this is true also of the "rudemarks" with the exception that more gravel and stones are found in them than in the plant-covered ground. As mentioned above, there is no direct connection between the mud-flow phenomena and the "rudemarks" and knolls, but it may happen that a flat with either of these surface-forms is afterwards affected by mud-flows; this is then a secondary phenomenon. Where subsoil-ice is absent, as for instance in the neighbourhood of the hot springs which are scattered in hundreds all over the country, I do not remember to have seen "rudemarks" or "thufur" proper. Upon the plateau itself "rudemarks" are rather rare, but, on the other hand, various mud-flow phenomena are common; thus, stones are often seen arranged in bands on the slopes, and in various other ways which, however, I regret to say, have not as yet been more closely investigated. On basaltic plateaus covered with coarse basalt-gravel and blocks of rock, patches of clay are now and then seen which appear, in the middle, to have thrust up from below and spread out slightly on all sides.

Besides these knolls there are many other similar eminences in the gravel-covered ground which are called knolls, but are due to quite different causes and have a different origin. Sometimes nodules on the greensward are due to the form of the substratum, as where a thin layer of soil occurs upon lava, or upon a stony and rugged bottom. In blown sand, knolls are formed around roots of *Elymus arenarius*, *Halianthus peploides* and other plants. Where the ground-water stands very high, as in many extensive boggy tracts, so that the entire surface freezes into an ice-cake, only small knolls of organic material are seen, formed of moss and Carices. On hard grassland, on gravelly flats and similar places, small



knolls are formed of the rootlets, leaf-rosettes, etc. of various plants. Sometimes knolls are formed of organic material in places where a small spot is constantly manured, e. g. the so-called "bird-knolls" on higher levels, where birds of prey are in the habit of alighting, and the characteristic Icelandic "dog-knolls" (hundapúfur) along the roads where the dogs are wont to stop, which almost all travellers in Iceland have for companions.

### III. CLIMATE.<sup>1</sup>

**A**LONG the coast of Iceland, generally speaking, a decidedly insular climate prevails, the conditions of which are determined by the wind-distribution over the North Atlantic and by oceanic currents. The climate has an oceanic character, the summer being cool and the winter usually mild — but it may become very cold when northern winds prevail and the Polar ice blockades the coasts. The air is usually damp, and storms are very frequent and violent. The climate varies, however, rather considerably in the different parts of the coast, and there is also a considerable difference between that of the coast and the interior.

<sup>1</sup> Meteorological observations from Iceland are published annually in "Meteorologisk Aarbog," 2. Del. Bilandene. Kobenhavn (Annuaire Météorologique. Publié par l'Institut météorologique Danois. Deuxième partie. Les colonies), in Danish and French. See also. *Eléments météorologiques des îles Féroé, de l'Islande et du Groenland*. Copenhagen, 1899. The climatological observations from Iceland have, as yet, been worked out to a small extent only, and there exist no larger and more exhaustive accounts of the climate of Iceland; only some small, but valuable, papers are to hand by V. Willaume-Jantzen (*Climat du littoral islandais*. Congrès maritime international de Copenhague, 1902; and some articles in "Salomonsens Leksikon," 1899, and in "Atlanten," 1904); use has been made of these in this paper. The climatological means which are given in this paper have been calculated and classified at the Meteorological Institute in Copenhagen in 1910, and were previously published, 1911, only in my book on Iceland "Lýsing Islands," in which there is a section (vol. II, pp. 327—394) giving an account of our present knowledge of the climate of Iceland and its weather-conditions during historic times. Among older papers on the climatology of Iceland may be mentioned J. Thorstensen, *Observationes Meteorologicæ, 1823—1837, in Islandia factæ*. Hafniæ, 1839; J. F. Schouw, *Nogle Bemærkninger om Vejrliget paa Island i Vinteren 1824—25* (Tidskrift for Naturvidenskaberne. København, 1826, IV, pp. 259—262); Mag. Pedersen, *Undersøgelse om Barometrets daglige Middelocillation paa Island* (Overs. Vid. Selsk. Forh., 1845, pp. 65—69); and lastly observations by H. J. Scheel from Akureyri, 1811—13 (*Annals of Philosophy*. Edited by Th. Thomson, Series 1, Vol. XI, London, 1818, pp. 96—103 and 169—175), and observations by A. O. Thorlacius from Stykkisholm, published in "Journal of the Scottish Meteorological Society," 1869, 1873, etc. Articles on the winds, drift-ice and other more special subjects will be mentioned subsequently in footnotes to the text.

The climate of Iceland, owing to oceanic currents, is much milder than could be expected from the position of the island. As is well-known the temperature of the air varies greatly at the same latitude on the eastern and western sides of the North Atlantic. Stykkisholm in Iceland lies about  $65^{\circ}$  N. lat. as also Brönö in Norway and Angmagsalik on the east coast of Greenland, but the temperature varies greatly in these three places as shown in the following table: —<sup>1</sup>

	February	July	Average for year
Brönö .....	— $1.4^{\circ}$ C.	$12.8^{\circ}$ C.	$5.2^{\circ}$ C.
Stykkisholm .....	— $2.7^{\circ}$ C.	$9.7^{\circ}$ C.	$2.8^{\circ}$ C.
Angmagsalik .....	— $10.8^{\circ}$ C.	$5.4^{\circ}$ C.	— $2.6^{\circ}$ C.

The above table shows, among other things, the great influence exerted by the cold, ice-carrying current in Denmark Strait. On the whole, oceanic currents have a great effect upon the climate of Iceland. The west coast has its temperature raised by the Gulf Stream. One branch of this passes Cape Nord and continues its course along the north coast where it becomes cooled, but has still a comparatively high temperature which is distinctly felt at Grímsey. Another branch of the Gulf Stream comes from the south up towards the south and east coasts where it meets the cold Polar current which comes down along the east coast of Greenland and at Iceland divides into two branches. Of these branches the one broad branch turns down through Denmark Strait, while the other flows down towards Langanes, and thence southwards along the east coast of Iceland to South Iceland where it passes between the coast and the warm current outside. The conditions connected with these currents exert a great influence upon the temperature of the ocean off different parts of the coast and thus upon the flora and fauna of the ocean, which differ greatly according to whether they are under the influence of cold or warm water. Thus, the algal vegetation along the north-eastern coast of Iceland has a different character — is more Polar — than towards the south-west; this applies also to the fish fauna, and the deep-water, spot-bound fauna, as well as to the plankton.

The temperature of the surface-water of the ocean varies therefore in no slight degree off the different parts of the coast. During winter the temperature of the ocean-water off the east coast, where the influence of the Polar current is greatest, is on an average  $0.8^{\circ}$

<sup>1</sup> Julius Hann: Handbuch der Klimatologie. Stuttgart, 1908, I, p. 181.



**Table I. Mean Temperature of the Surface Water of the Ocean round Iceland for the Period 1872—1906. (Centigrade scale used.)**

Name of Station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for year
Stykkisholm...	0.9	0.3	0.4	1.7	4.7	8.2	10.4	10.6	9.1	6.3	3.7	1.8	1.0	2.3	9.7	6.4	4.7
The Vest-mannaeyjar.	4.1	4.1	4.5	6.1	7.7	9.5	10.9	10.8	9.1	6.8	5.1	4.1	4.1	6.1	10.4	7.0	6.1
Papey....	0.7	0.4	0.5	1.5	3.1	4.8	6.0	6.6	6.2	4.3	2.6	1.3	0.8	1.7	5.8	4.4	3.1
Grímsey.....	1.8	1.4	0.7	1.3	2.6	4.2	6.6	7.4	6.9	5.3	4.1	2.9	2.0	1.5	6.1	5.4	3.1

The temperature-conditions of the coastal districts correspond very closely with those of the ocean. The north-east coast has, on an average, a mean winter-temperature of from  $-2^{\circ}$  to  $-4^{\circ}$  C., a summer temperature of  $6^{\circ}$  to  $7\frac{1}{2}^{\circ}$  C., and a mean for the whole year of  $1^{\circ}$  to  $2^{\circ}$  C.; while the south-west coast has a winter temperature of  $0^{\circ}$  to  $-2^{\circ}$  C., a summer temperature of  $9^{\circ}$  to  $10^{\circ}$  C., and one for the whole year of  $3^{\circ}$  to  $4^{\circ}$ . When the Greenland drift-ice blockades the coast, the difference between these temperatures is considerably greater. In the severe ice-year, 1881, the difference between the temperature on the isle of Grímsey and in the Vest-mannaeyjar, from January to March, was  $10\frac{1}{2}^{\circ}$  to  $14^{\circ}$  C., while normally in these months it is only  $3\frac{1}{2}^{\circ}$  to  $5\frac{1}{2}^{\circ}$ ; in the same months (in 1881) the difference of temperature between Stykkisholm and the Vestmannaeyjar was  $7^{\circ}$  to  $10^{\circ}$  C., while normally it is only  $3^{\circ}$  to  $4^{\circ}$ . Therefore the temperature varies very greatly from year to year, and so also does the mean of the different months. For instance, take the month of March: at Stykkisholm the highest mean temperature in a period of 33 years was  $2.9^{\circ}$  C.; and the lowest mean in the same period was  $-13.3^{\circ}$  C. From this it will be seen that the Polar current, and especially the drift-ice, exercises a great influence upon the climate in Iceland and thereby upon the vegetation and the means of sustenance of the people. When the Polar ice arrives at the north coast the temperature immediately falls: when in May and June the people who live in South Iceland see that it is snowing on the mountains, they at once take it as a sign that the dreaded drift-ice is about to blockade the coast of



North Iceland. So long as the ice drifts backwards and forwards along the coast, the weather continues to be very changeable and stormy; but once the ice has been grounded on the land, the weather becomes more settled, although colder. The parts of the coast which are most subject to be blockaded by the drift-ice are the north and east sides of the north-western peninsula, especially Strandasysla, and Langanes and Melrakkasljetta. In these districts the effect of the presence of the drift-ice is shown both in the wider extension of the snow-wreaths and in the character of the vegetation. On the east coast of the north-western peninsula, south of Cape Nord (also called Cape Horn) there is no vestige of coppice-wood, while this occurs luxuriantly on the western and south-western side of the peninsula, and at the heads of the fjords. Cabbage and potato plots are also absent along this coast, north of  $65^{\circ} 40' \text{ N. lat.}$ ; while small plots of cabbages occur frequently in Aðalvík on the north-western coast of the peninsula at  $66^{\circ} 25' \text{ N. lat.}$  Even at the head of Hunaflói the influence of the drift-ice is evident: *Chamænerium latifolium* which flowers every year on the plateau, 600—700 metres above sea-level, flowered only twice during eleven years (1878—88) at Midfjörður. In the districts which are most exposed to the effects of the Polar ice, the herbage is extremely poor owing to the constant coldness of the springs and the rawness of the summers; the frequent snow-falls even at midsummer, make hay-making precarious, so that the sheep and cattle — and thereby the inhabitants — are liable to suffer want.

During the nineteenth century the coast of Iceland has been free from ice on an average about one year in every four or five; but no rule can be formulated for the arrival of the Polar ice on the coast of Iceland; sometimes it remains absent for many years: sometimes it visits the coast several years in succession. The ice arrives at different times — as a rule from January to April; if it arrives early, it usually drifts away soon without doing any great damage, but if it arrives near the time of spring, it often remains till far into summer, and causes much inconvenience, hindering navigation and fishing, spoiling the hay-harvest, etc. But it almost invariably drifts away at the end of August, and for the last four months of the year the coast is almost always free from ice. As a rule, the Polar current first carries the drift-ice to the north-western peninsula of Iceland, off Cape Nord, and the main mass is carried out through Denmark Strait; but that part of the ice which besets

Hornstrandir (the coast down either side of Cape Nord), is carried by the coastal current (the Irminger Current) along Strandasysla into Hunaflói, from thence outwards along the east coast of this fjord, then further eastwards along the entire north coast, past Langanes and on, down to the east and south coasts, where it either melts or else drifts away into the open sea. The ice which comes to South Iceland always comes from the east, never from the north-west. In severe ice-years the drift-ice may blockade the whole of the south coast as far as to Cape Reykjanes; on the other hand, it very rarely happens that any drift-ice enters Faxaflói and more rarely still that any icebergs drift past the north-western fjords into Breiðifjörður; the ice is not known to have been grounded on the land, down past Patriksfjörður, for the last 200 years. The most severe ice-year known was the year 1695; in that year drift-ice surrounded the whole island with the exception of Snæfellsnes — a fact unparalled in the history of the country. In most of the places the ice occurred in such quantities in that year that open water was not visible from the highest mountains. As usual the ice drifted from North Iceland to South Iceland and then southwards and reached Thorlakshöfn as early as April; from thence it drifted into Faxaflói as far as Hítárós, and from the north-west the ice drifted past Látrabjarg into Breiðifjörður. In the beginning of May it was possible to walk and ride everywhere outside all the fjords of North Iceland. It sometimes happens that the drift-ice drifts to Langanes and then down to the east coast without touching the north coast.<sup>1</sup> The Polar current bears great quantities of drift-wood to the northern coast of Iceland, most frequently to the neighbourhood of Cape Nord and Langanes. The greater part of this drift-wood starts probably from Siberia; that of most common occurrence is *Larix sibirica*, *Picea obovata*, *Abies sibirica*, *Pinus cembra*, *Pinus silvestris*, *Populus tremula*, *Salix vitellina*, and others.<sup>2</sup>

<sup>1</sup> Th. Thoroddsen: Den grönländska drifisen vid Island (Ymer. Stockholm, 1884, pp. 145—160). C. Ryder: Isforholdene i Nordhavet, 1877—1892 (Tidsskrift for Søvesen, 1896). V. Garde: Isforholdene i de arktiske Have in Nautisk Meteorologisk Aarbog of 1898 and subsequent years (in Danish and English). W. Meinardus: Periodische Schwankungen der Eisdrift bei Island (Annalen der Hydrographie und Maritimen Meteorologie, 1906).

<sup>2</sup> J. G. Agardh: Om den Spetsbergiska Drifvedens ursprung (Övers. af Kgl. Vet. Ak. Förh., 1869, No. 2, pp. 97—119). A. G. Nathorst: Två somrar i norra Ishavet. Stockholm, 1900, I, p. 345. Th. Thoroddsen: Ferðasaga af Vestfjörðum (Andvari, XIII, 1887, pp. 164—168) and Ferðabók, II, 1914, pp. 63—70. Compare Geografisk Tidsskrift, IX, p. 45. E. Olafsson: Rejse gennem Island (1772), I, pp. 508—513. O. Olavius: Oekonomisk Rejse gennem Island (1780), pp. 126—146.

The drift-ice also carries to the coast of Iceland fragments of rock which are not found in Iceland (gneiss, granite, talc-slate, mica-slate, etc.), and also gravel, clay and earth from other Arctic countries. Moreover, the warm water of the Gulf Stream sometimes carries drift-material with it from southern parts, e. g. mahogany, sugarcane, "nuts" of *Entada Gigalobium*, *Mucuna urens*, *Guilandina Bonducella*, etc.

The weather of the North Atlantic Ocean depends upon the winds, which also exercise a great influence upon the currents around Iceland. The mean atmospheric pressure in the North At-

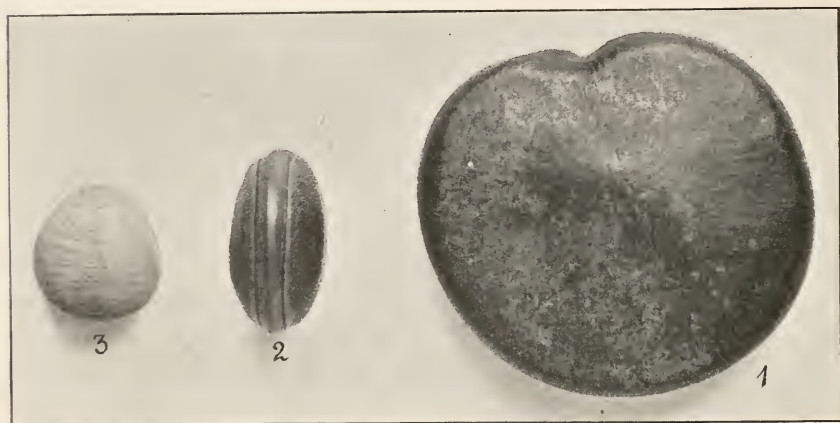


Fig. 20. Seeds of *Entada Gigalobium* (1), *Mucuna urens* (2), and *Guilandina Bonducella* (3).

lantic is generally lowest to the south-west of Iceland but there is, in addition, another centre of low barometric pressure north-east of Iceland; on the whole, the direction of the winds over Iceland is determined by this. In West and North Iceland the majority of the winds blow from SE., E. and NE., while on the east coast winds from the NE. and NW. are nearly equally numerous (20 % and 17 % relatively) because here both the above-mentioned centres of low atmospheric pressure try to prevail. This is true of the average condition only, because in reality the wind-conditions from day to day are very variable, as the ocean here is constantly visited by moving centres of depression. The barometer in Iceland is subject to very great changes. In Reykjavík the barometer, during a period of 28 years, has oscillated between 789 mm. and 697 mm.; at Stykkisholm, during one of 33 years, between 789 mm. and 700.3 mm.; in the Vestmannaeyjar during a period of 29 years, from 789 mm. to

Table II. Atmospheric Pressure along the coast of Iceland for the Period 1872—1906:  
700 mm. +, reduced to 0° C., and to sea-level.

Name of station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for the year
<b>Stykkishólmur.</b>																	
From $\frac{1}{16}$ 1873 to $\frac{31}{12}$ 1906.																	
Mean Atmospheric Pressure . . .	49.0	51.6	54.4	57.2	60.7	58.9	57.4	57.4	54.5	54.7	52.5	48.9	49.8	57.4	57.9	53.9	54.8
Mean of maximum pressure . . .	66.8	65.5	66.4	63.6	65.7	65.2	62.5	63.9	62.9	67.6	64.7	65.2					57.9
Mean of minimum pressure . . .	36.8	36.4	40.5	47.6	51.3	52.4	51.4	50.5	47.4	45.7	42.5	40.8					52.0
Absolute maximum pressure . . .	85.2	89.1	88.5	79.4	83.5	78.8	74.0	73.6	75.0	82.7	80.3	83.6					89.1
Absolute minimum pressure . . .	5.7	0.3	12.3	18.0	30.3	25.2	30.7	24.0	14.8	20.6	13.2	3.7					0.3
<b>Vestmannaeyjar.</b>																	
From $\frac{1}{7}$ 1877 to $\frac{31}{12}$ 1906.																	
Mean Atmospheric Pressure . . .	49.3	51.9	53.1	56.3	60.4	59.4	57.3	56.7	54.4	54.5	50.9	48.1	49.8	56.6	57.8	53.3	54.4
Mean of maximum pressure . . .	63.9	65.8	66.8	61.9	64.0	64.9	61.6	64.1	64.7	61.6	61.8	55.3					57.2
Mean of minimum pressure . . .	36.1	37.3	37.9	47.5	54.9	54.4	50.1	50.1	49.0	45.2	41.2	41.4					51.9
Absolute maximum pressure . . .	88.5	87.5	89.0	80.2	83.0	77.9	71.9	75.3	74.8	80.2	81.4	79.2					89.0
Absolute minimum pressure . . .	6.4	699.2	15.7	18.0	30.3	23.6	33.7	32.3	18.1	15.5	5.6	5.5					699.2
<b>Berufjörður.</b>																	
From $\frac{1}{12}$ 1872 to $\frac{31}{12}$ 1906.																	
Mean Atmospheric Pressure . . .	50.4	53.3	54.9	58.2	61.1	59.5	57.7	57.4	55.5	55.2	53.4	50.5	51.4	58.1	58.2	54.7	55.6
Mean of maximum pressure . . .	65.9	67.2	65.8	64.1	65.4	65.9	62.2	63.8	64.6	66.1	63.8	63.9					58.1
Mean of minimum pressure . . .	37.1	39.4	40.8	47.5	52.4	53.9	51.3	50.5	48.6	46.2	44.0	44.1					53.1
Absolute maximum pressure . . .	87.8	88.7	87.7	80.5	83.2	77.7	72.9	73.8	76.7	79.9	80.0	81.4					88.7
Absolute minimum pressure . . .	7.8	4.9	16.0	18.0	28.1	31.3	35.9	34.5	21.3	21.0	13.7	6.2					4.9
<b>Akureyri.</b>																	
From $\frac{1}{7}$ 1873 to $\frac{31}{12}$ 1906.																	
Mean Atmospheric Pressure . . .	50.7	53.3	55.6	63.6	61.5	59.4	57.8	57.9	55.5	55.9	53.9	50.6	51.5	58.5	58.4	55.1	55.9
Mean of maximum pressure . . .	68.4	67.0	66.7	65.3	66.8	66.1	62.5	64.6	63.7	68.1	64.7	63.9					58.4
Mean of minimum pressure . . .	38.1	38.7	43.3	49.2	52.1	53.2	51.6	51.0	48.0	47.3	45.0	43.3					52.5
Absolute maximum pressure . . .	85.6	89.0	88.2	83.8	83.9	77.6	73.2	74.3	77.2	83.5	81.2	81.5					89.0
Absolute minimum pressure . . .	8.8	5.7	15.2	19.6	30.1	26.0	34.8	28.6	18.4	17.1	15.3	8.1					5.7



Table III. Prevailing Winds expressed as percentages.

Name of station	January	February	March	April	May	June	July	August	September	October	November	December	Average for the year
<b>Vestmannaeyjar</b> ( <sup>1</sup> / <sub>7</sub> 1877 to <sup>31</sup> / <sub>12</sub> 1906).													
N.....	13	13	18	13	10	4	7	10	11	18	17	17	12
NE.....	3	4	3	3	2	2	1	2	1	4	4	3	3
E.....	19	22	24	27	27	24	20	23	26	21	20	18	22
SE.....	9	8	8	10	10	14	13	9	10	9	8	8	10
S.....	10	10	9	9	8	9	5	5	9	8	9	10	8
SW.....	16	13	9	7	8	10	9	9	11	8	12	14	11
W.....	8	9	7	7	8	9	13	8	6	6	6	7	8
NW.....	3	3	4	5	4	4	7	4	4	4	4	3	4
Calm.....	19	18	18	19	23	24	25	30	22	22	20	20	22
<b>Papey</b> ( <sup>1</sup> / <sub>8</sub> 1873 to <sup>31</sup> / <sub>12</sub> 1906).													
N.....	11	15	13	12	10	5	5	8	7	12	14	11	10
NE.....	11	13	18	26	27	24	26	24	19	16	15	12	20
E.....	4	7	6	8	9	13	10	10	8	8	6	6	8
SE.....	5	5	5	6	5	6	6	5	6	5	4	5	5
S.....	7	7	6	8	7	10	10	8	8	5	6	7	8
SW.....	19	17	12	12	14	18	13	12	20	14	15	17	15
W.....	9	6	5	3	4	5	5	3	5	5	6	7	5
NW.....	24	20	24	15	13	5	6	10	14	24	25	27	17
Calm.....	10	10	11	10	11	14	19	20	13	11	9	8	12
<b>Stykkishólmur</b> ( <sup>1</sup> / <sub>6</sub> 1873 to <sup>31</sup> / <sub>12</sub> 1906).													
N.....	5	5	5	6	6	5	5	9	6	8	6	7	6
NE.....	14	17	18	17	16	10	10	12	15	19	20	14	15
E.....	21	23	24	25	21	18	21	21	19	22	21	24	22
SE.....	16	15	15	15	14	14	10	10	15	17	16	14	14
S.....	13	11	9	10	11	13	9	9	13	11	9	10	11
SW.....	16	15	12	6	6	8	6	5	10	9	12	16	10
W.....	5	4	5	6	8	12	15	11	7	4	5	4	7
NW.....	1	1	1	1	4	7	8	6	2	1	1	1	3
Calm.....	9	9	11	14	14	13	16	17	13	9	10	10	12
<b>Grímsey</b> ( <sup>1</sup> / <sub>7</sub> 1873 to <sup>31</sup> / <sub>12</sub> 1906).													
N.....	8	8	9	7	8	5	8	7	6	6	8	9	7
NE.....	16	18	18	19	20	12	13	12	13	19	21	16	17
E.....	15	19	20	26	27	27	28	27	23	21	20	16	22
SE.....	20	21	20	16	10	11	9	12	17	18	15	20	16
S.....	7	7	5	4	2	3	2	2	5	6	6	8	5
SW.....	9	6	5	3	2	3	2	2	5	6	7	8	5
W.....	14	12	12	10	9	10	10	10	13	11	13	12	11
NW.....	5	5	5	5	9	10	11	12	8	6	6	6	7
Calm.....	6	4	6	10	13	19	17	16	10	7	4	5	10



699.2 mm.; at Berufjord during a period of 34 years, from 788.7 mm. to 704.9 mm.; and at Akureyri, during one of 33 years, from 789 mm. to 705.7 mm. The paths of the moving centres of depression lie especially frequently south of Iceland so that one centre of depression after the other crosses the Atlantic from the west with a main direction of east or north-east; sometimes nearer, sometimes further from Iceland. This movement of low pressure centres causes the wind to veer towards the sun, especially from S. or SE. through E. and NE. Table III shows that at Stykkisholm, very frequently the winds blow from S. and SW. (such from 11 % and 10 % respectively) which is due to the fact that Denmark Strait also provides a path for the moving centres of depression; they come from the south and cause on Iceland a veering of the wind with the sun from SE. or S. through SW. It is probably these centres of depression which cause the rather frequent winds from the W. and SW. at Grímsey and Papey respectively. There may, however, occur longer periods in which the winds of Iceland are rather constant, the lowest atmospheric pressure over the North Atlantic remaining at the same place. The wind-conditions are generally favourable for Iceland, the warm air from the Atlantic Ocean is carried in over the land, while it is rare for cold winds to be thus brought during winter. According to observations taken at Stykkisholm on the west coast, the warmest winds there are the SE., S. and SW. while the greatest cold is caused by the N., NE. and E. winds. The difference between the temperature induced by the warmest and by the coldest winds is on an average  $9^{\circ}$ — $10^{\circ}$  C. in the months of December to April, and  $4^{\circ}$ — $6^{\circ}$  C. in the other months. The temperature may show great differences according to whether northerly or southerly and easterly winds are the prevalent ones for any length of time; thus, the mean temperature at Stykkisholm in March 1856 was  $+4.3^{\circ}$  when southerly winds prevailed, and in March, in the ice-year 1881, the mean temperature was  $-13.3^{\circ}$  when easterly winds were prevalent.<sup>1</sup> Conditions pertaining to the atmospheric pressure over the Atlantic, which is specially

<sup>1</sup> V. Willaume-Jantzen: *Climat du littoral islandais*, 1902. N. Hoffmeyer: *Die Vertheilung des Luftdruckes über den nord-atlantischen Ocean während des Winters und deren Einfluss auf das Klima von Europa* (Zeitschrift für Meteorologie. Wien, 1878. Bd. XIII. Nr. 22). N. Hoffmeyer: *Etude sur les tempêtes de l'Atlantique septentrional*. Copenhagen, 1880. G. Rung: *Répartition de la pression atmosphérique sur l'océan atlantique septentrional*. Copenhagen, 1894. V. Garde: *Vindkort over den nordligste Del af Atlanterhavet* (Nautisk-meteorologisk Aarbog for 1899. København, 1900. S. 25—46).



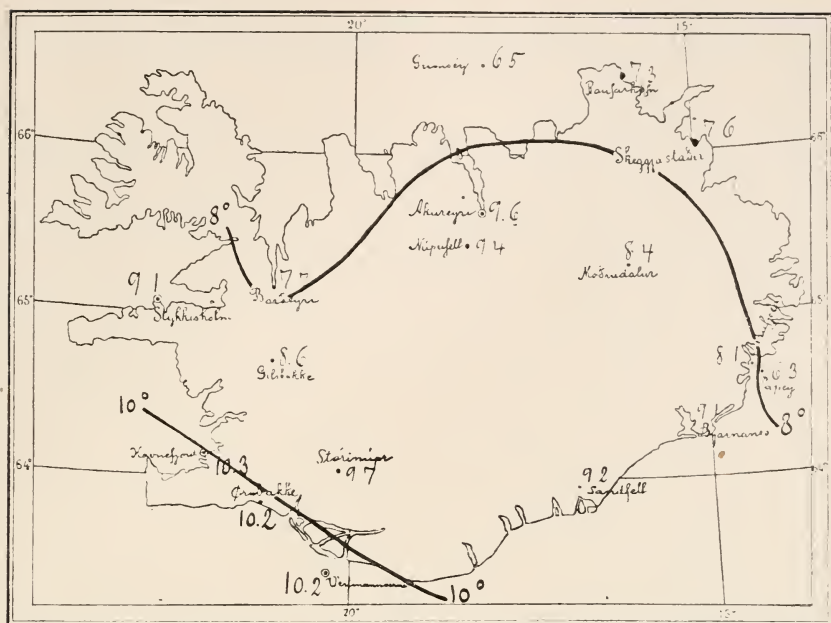


Fig. 23. The mean summer temperatures for the period 1874—1901. (V. Willaume-Jantzen.)

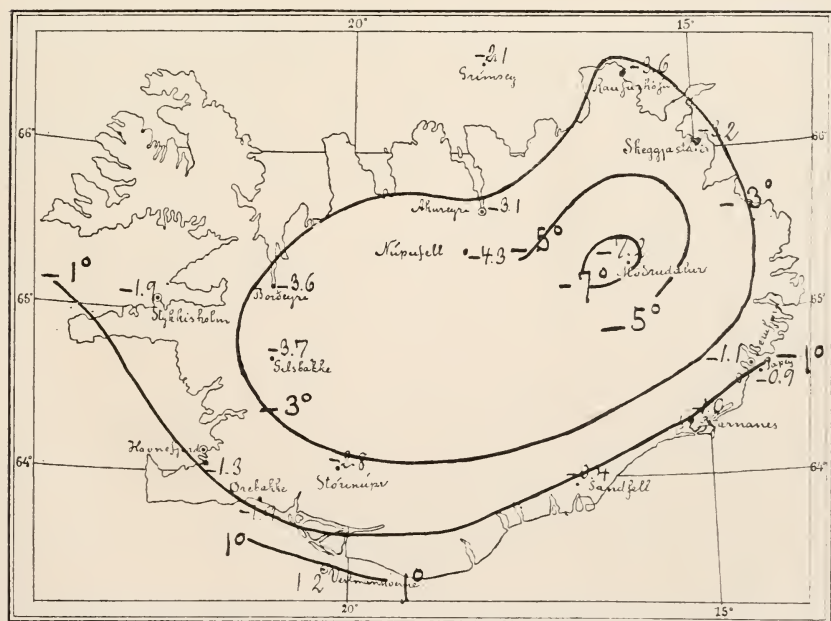


Fig. 24. The mean winter temperatures for the period 1874—1901. (V. Willaume-Jantzen.)

expressed in the height of the barometer at Iceland and in the Azores, have, as is well-known, a very great influence upon the climate of western Europe.<sup>1</sup>

The wind blows with great force over Iceland and storms are frequent, especially in the winter half of the year. At Stykkisholm there are, on an average, 50 days of storm annually; in the Vestmannaeyjar 25; and on Grímsey 11. On the west coast the majority (60 %) of the storms are from the NE., while in East Iceland the NW. wind is the most stormy, causing 50 %. As the fisheries along the coast of Iceland are carried on especially in the winter half of the year (the fishing season along the south-west coast begins in February), the storms constantly cause a great many disasters at sea. During the years 1850—1877 (with the exception of 1853 and 1875, for which no data are to hand) 2008 people were drowned off Iceland, forming 3 % of the total number of deaths during those years; of these, 60 % were drowned in March. During the years 1881—1910, 2096 persons were drowned out of a population of 70,000—80,000. Both in northern and eastern Iceland the Föhn wind, which blows down from the Jökulls of the plateau, is fairly common during winter and causes a sudden rise of temperature, resulting in the melting of the snow in the lowlands and of the ice upon the surface of the lakes and rivers. N. Hoffmeyer<sup>2</sup> describes a Föhn wind which blew down from Vatnajökull over south-east Iceland from September 18th to 26th, 1877, causing the temperature at Berufjord and on Papey to rise from 7°—8° C. to as much as 18°—20° C.; otherwise, such a high temperature is very rare at these stations, even at midsummer.

The oceanic character of the Icelandic climate is manifested in the low degree of heat experienced during summer and the mildness of the winter. The mean temperature of the coldest days along the coast of Iceland (Stykkisholm, Berufjord and Grímsey) was in

<sup>1</sup> J. Hann: Die Anomalien der Witterung auf Island in dem Zeitraume 1851 bis 1900 und deren Beziehungen zu den gleichzeitigen Witterungsanomalien in Nordwestevropa (Sitzungsberichte d. Akademie d. Wissenschaften in Wien. Math.-naturw. Klasse. Band 113, Abteilung II a, Wien, 1904. S. 183—269). H. H. Hildebrandsson: Quelques recherches sur les centres d'action de l'atmosphère IV. Sur la compensation entre les types des saisons simultanés en différentes régions de la terre (Kungl. Svenska Vetenskapsakademiens Handlingar, Band 45, No 11. Stockholm, 1910).

<sup>2</sup> N. Hoffmeyer: Vejrforholdene paa Island i Vinterhalvaaret 1877—78 (Tidskrift for populær Fremstilling af Naturvidenskaben, 5. Række, V Bind, 1878, pp. 161—172).





February and in the first half of March —  $2^{\circ}$  to  $-4^{\circ}$  C., which is only from  $1^{\circ}$  to  $3^{\circ}$  colder than the average temperature of the coldest days in Copenhagen; but, on the other hand, the warmest days in Iceland, which occur in the latter half of July and in August have, on an average, a temperature of only from  $7^{\circ}$  to  $10^{\circ}$  C. There are, however, numerous oscillations from year to year, mostly during winter, less frequently during summer. The normal temperature is below zero (Celsius) from the last days in November to the first days in April, or even May 1st on Grímsey. Therefore the Icelandic summer is very unfavourable to plant-life, the temperature being so low during growth-period. The highest mean temperatures for any month fall in July and August and even these reach only to  $11^{\circ}$ — $12\frac{1}{2}^{\circ}$  C. (Papey  $8.5^{\circ}$  and  $9.6^{\circ}$ ; Vestmannaeyjar  $12.7^{\circ}$  and  $12.3^{\circ}$ ) — the temperature of a mild May or cool September in Copenhagen. By exception, on some days, the heat may be very great; the greatest amount of heat registered at Berufjord was  $26.3^{\circ}$  C., on Grímsey  $26.2^{\circ}$  C., at Stykkisholm  $22.9^{\circ}$  C., and in the Vestmannaeyjar  $21.2^{\circ}$  C. But in the interior of the island — in the valleys — a higher temperature ( $27^{\circ}$ — $28^{\circ}$  C.) has occasionally been registered. The lowest temperature registered at Berufjord was  $-23.1^{\circ}$ , in the Vestmannaeyjar  $-20.9$ ; at Stykkisholm  $-26^{\circ}$ , and on Grímsey  $-30^{\circ}$ .<sup>1</sup> At the coast in Iceland the average temperature of the day and night rarely exceeds  $15^{\circ}$  C., and at Berufjord there occur, as a rule, during the year, only four days with such a temperature, but in Mödrudalur six to seven; a fact which shows among other things that the summer temperature is often higher in the interior of the country, while the cold there is also greater during the winter. On ascending to the interior districts the climate is found to be no longer so decidedly oceanic as along the coasts, and the vegetation also increases in density the further one proceeds upwards, following the valleys. Coppice-woods often thrive at the head of valleys in places where birch-coppices cannot grow out at the coast. The mean temperature of the coldest day and night in Mödrudalur was  $-29^{\circ}$  C., at Berufjord  $-19^{\circ}$  C. During the period March 6—12, 1892, when the cold was very severe, the mean tempera-

<sup>1</sup> All these figures are those for the cold, drift-ice winter 1880—1881. But it should be mentioned here that the Grímsey station had no maximum thermometer, and that the temperature  $-30^{\circ}$  C. was one which was registered during the day. In reality the cold had probably been greater, because in the same winter I noted early in the morning of some days, at Mödruvellir in Hörgárdal a temperature of  $-32^{\circ}$  to  $-36^{\circ}$  C.

ture in the Vestmannaeyjar was  $-7^{\circ}$  C., at Berufjord  $-11\frac{1}{2}^{\circ}$  C., on Grímsey  $-15\frac{1}{2}^{\circ}$  C. and in Mödrudalur  $-24\frac{1}{2}^{\circ}$  C.

The mean temperature for the whole island, according to the observations to hand, is  $2\frac{1}{2}^{\circ}$  C., but the real temperature is undoubtedly considerably lower, because only one station on the immense plateau, was included. The mean temperature of the winter on the north and east coasts ranges between  $-1^{\circ}$  and  $-3\frac{1}{2}^{\circ}$  C., and of the summer between  $6\frac{1}{2}$  and  $8^{\circ}$  C., of South Iceland the mean temperature for the winter ranges between  $0^{\circ}$  and  $-2^{\circ}$  C., and the summer temperature between  $9$  and  $10^{\circ}$ . The difference between the summer and winter temperatures increases with the distance from the sea, as shown in Fig. 26. The difference is greatest between the plateau and the Vestmannaeyjar. The mean temperature for the year in Mödrudalur is  $-0.4^{\circ}$  C., and in the Vestmannaeyjar  $5.3^{\circ}$  C.; the mean summer temperature of Mödrudalur  $8.4^{\circ}$  C. and of Vestmannaeyjar  $10.2^{\circ}$  C.; and the winter temperature of Mödrudalur  $-7.2^{\circ}$  C., and of Vestmannaeyjar  $+1.2^{\circ}$  C.; thus the winter in Mödrudalur is  $8^{\circ}$  colder than in the Vestmannaeyjar. The south coast is the warmest part of the country, and in the Vestmannaeyjar the mean temperature of none of the months is below freezing point. The mean temperature for the year on the south coast is as follows: — Bjarnanes  $3.7^{\circ}$  C., Sandfell in Öraefi  $4^{\circ}$ , Eyrarbakki  $3.6^{\circ}$ , Havnefjord  $3.9^{\circ}$  and Reykjavík  $4.2^{\circ}$ . The climate of the coast of Iceland is said to be mildest below Eyjafjöll and in Mýrdalur, but no observations are to hand from these two places.

**Table IV. Account of the Air Temperature along the coasts, in the interior districts, and on the plateau, according to the seasons.**

	Number of stations	Winter	Spring	Summer	Autumn	The year
The Vestmannaeyjar . . . . .	1	1.2	4.1	10.2	5.5	5.3
South-west coast (Stykkisholm-Eyrarbakki)	3	-1.7	2.0	9.9	3.8	3.5
South-east coast (Sandfell-Berufjord) . . . .	4	-0.8	1.8	8.2	3.8	3.3
North-east coast (Skeggjastaðir-Grímsey) .	3	-3.0	-1.0	7.1	2.2	1.3
Interior districts (with the exception of Mödrudalur) . . . . .	5	-3.5	0.4	9.0	2.3	2.1
Plateau (Mödrudalur) . . . . .	1	-7.2	-2.1	8.4	-0.7	-0.4
The whole island . . . . .	17	-2.4	0.8	8.7	2.9	2.5

Table IV shows that the climate of the interior districts is more continental than that at the coast, the summers being warmer and the winters colder. The differences in the temperature of the stations at the head of a fjord is greater than of those situated outside; Berufjord, for instance, is warmer than Papey. There are, however, exceptions to this in places where cold currents and drift-ice exert an influence; thus Bordeyri at the head of Húnaflói has the same annual temperature as Grímsey, — Raufarhöfn and Skeggjastaðir are even colder, being much influenced by the Polar currents.

During a period of 33 years (1873—1906) there have been on an average 166 frosty days annually at Stykkisholm, 109 in the Vestmannaeyjar, 158 at Berufjord and 192 on Grímsey. At Stórinupur near the southern lowlands, at a height of 135 metres above sea-level, during a period of 20 years, there have been on an average 200 frosty days. The frost appears early and disappears late. Frosty days are frequent till far into early summer, but in South and West Iceland midsummer is usually free from frost. On Grímsey it freezes in all the months of the year, but in July and August there are on an average only two frosty days monthly; at Berufjord, in the Vestmannaeyjar and at Stykkisholm, July has been free from frost during a period of 33 years. On the northernmost peninsulas and in districts situated at the highest levels there is no doubt that none of the months is entirely free from frost. When drift-ice lies along the coast in North Iceland the ground is usually frost-bound throughout summer, and in the vast extents of bog-land on the plateau, at a height of 400—500 metres the sub-surface ice never thaws entirely.

Table V shows the temperature at all the meteorological stations in Iceland during the years 1874—1901. The observations from the chief stations extend over a period of more than 25—28 years; at other stations 15—22 years and in some 5—12 years. For the sake of completeness some observations from three stations have been included, although they cover a period of 2—3 years only. Table VI gives many more and fuller information regarding temperature-conditions at the main stations during a period of 33 years (1872—1906).

The climate of Iceland is very damp although the precipitation is not considerable; it is, however, much greater than in Denmark. Sleet and drizzling rain are of constant occurrence, but the amount of precipitation on a single day is rarely sufficient to be of any con-

Table V. Mean Temperature in Iceland for the Period 1874—1901.

	Number of years	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for year
Stykkishólmur .....	28	-1.9	-2.3	-2.2	0.9	4.4	8.1	9.9	9.4	7.3	3.6	0.8	-1.5	-1.9	1.0	9.1	3.9	3.0
Borðeyri .....	12	-3.7	-4.0	-3.9	-0.3	3.0	6.8	8.1	8.1	6.1	2.3	-0.9	-3.1	-3.6	-0.4	7.7	2.5	1.6
Gilsbaki .....	7	-3.9	-3.7	-3.8	-0.4	4.0	7.9	9.4	8.6	6.1	1.6	-1.4	-3.5	-3.7	-0.1	8.6	2.1	1.7
Grímsey .....	27	-2.1	-2.8	-3.8	-1.2	1.9	5.4	7.1	7.0	5.8	2.4	0.1	1.4	-2.1	-1.0	6.5	2.8	1.6
Ákureyri .....	19	-3.2	-3.2	-3.5	0.8	4.7	9.0	10.4	9.3	6.3	2.0	-1.0	-3.0	-3.1	0.7	9.6	2.4	2.4
Núpuvell .....	5	-4.4	-3.9	-4.0	0.8	4.5	9.3	9.5	9.4	6.0	1.5	-2.2	-4.5	-4.3	0.4	9.4	1.8	1.8
Raufarhöfn .....	12	-3.8	-4.0	-4.9	-1.0	1.9	6.1	8.2	7.5	4.9	2.4	-1.5	-3.1	-3.6	-1.3	7.3	1.9	1.1
Skeggjastaðir .....	5	-3.7	-3.3	-4.2	-0.5	2.5	7.3	8.2	7.4	5.9	1.3	-1.3	-2.7	-3.2	-0.7	7.6	2.0	1.4
Möðrudalur .....	15	-7.8	-7.0	-7.2	-2.1	2.9	8.2	9.9	7.2	3.9	-1.4	-4.7	-6.8	-7.2	-2.1	8.4	-0.7	-0.4
Berufjörður .....	28	-1.3	-1.2	-1.8	1.3	4.1	7.1	8.7	8.4	6.7	3.2	0.9	-0.8	-1.1	1.2	8.1	3.6	3.0
Papey .....	27	-1.1	-1.1	-1.9	0.5	2.7	5.2	6.7	6.9	5.9	3.1	1.0	-0.5	-0.9	0.4	6.3	3.3	2.5
Bjarnanes .....	8	-1.2	-0.8	-0.9	3.2	5.4	8.2	9.8	9.2	7.3	3.6	0.8	-0.9	-1.0	2.6	9.1	3.9	3.7
Sandfell .....	5	-0.7	-0.1	-0.1	3.4	5.8	8.6	9.8	9.2	7.4	4.0	1.2	-0.3	-0.4	3.0	9.2	4.2	4.0
Vestmannaeyjar .....	25	1.1	1.4	1.4	4.1	6.7	9.2	10.9	10.5	8.3	5.2	3.1	1.1	1.2	4.1	10.2	5.5	5.3
Stórinúpur .....	18	-3.0	-2.4	-2.5	1.7	5.6	8.9	10.8	9.3	6.7	2.2	-0.7	-3.1	-2.8	1.6	9.7	2.7	2.8
Eyrarbakki .....	21	-2.1	-1.5	-1.6	2.4	6.1	9.3	11.0	10.3	7.5	3.0	0.2	-2.1	-1.9	2.3	10.2	3.6	3.6
Hafnarfjörður .....	22	-1.5	-0.9	-0.9	2.7	6.1	9.3	11.0	10.5	7.6	3.5	0.7	-1.5	-1.3	2.6	10.3	3.9	3.9
Reykjavík .....	27	-1.1	-0.8	-0.5	3.1	6.4	9.7	11.2	10.6	7.8	3.9	1.2	-1.2	-1.0	3.0	10.5	4.3	4.2
Áðalvík .....	2	-4.8	-4.1	-3.8	-1.1	3.1	7.1	9.6	7.5	5.9	2.1	-1.8	-3.3	-4.1	-0.6	8.1	2.1	1.4
Kóreksstaðir .....	3	-3.3	-3.1	-3.9	-0.2	3.2	7.9	9.9	8.2	6.3	1.5	-0.9	-2.9	-3.1	-0.3	8.7	2.3	1.9
Valbjófsstaður .....	3	-2.8	-2.9	-3.5	1.7	4.9	8.9	11.2	9.4	7.2	2.9	-0.7	-2.5	-2.7	1.0	9.8	3.1	2.8
Mean for the northern half of Iceland .....		-3.8	-3.8	-4.2	-0.4	3.3	7.6	9.0	8.2	5.8	1.7	-1.3	-3.3	-3.6	-0.4	8.3	2.1	1.6
Mean for the southern half of Iceland .....		-1.2	-0.8	-1.0	2.4	5.3	8.2	9.8	9.3	7.2	3.5	0.9	-1.0	-1.0	2.2	9.1	3.9	3.6
Mean for the whole island (17 stations) .....		-2.6	-2.4	-2.7	0.9	4.3	7.9	9.4	8.7	6.5	2.6	-0.3	-2.2	-2.4	0.8	8.7	2.9	2.5



Table VI. Mean Temperature along the coast of Iceland for the Period 1872—1906.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Winter	Spring	Summer	Autumn	Average for year
<b>Stykkishólmur</b>																	
From $\frac{1}{16}$ 1873 to $\frac{31}{12}$ 1906.	—2.0	—2.4	—2.2	0.7	4.3	8.2	9.9	9.3	7.3	3.5	0.7	—1.4	—1.9	0.9	9.1	3.8	3.0
Mean temperature.....	0.9	0.9	2.9	4.8	7.1	10.2	12.4	12.0	9.8	6.8	3.2	1.5					4.0
Highest mean temperature....	—8.6	—9.6	—13.3	—4.1	1.5	5.8	8.1	6.4	5.4	—0.4	—2.0	—7.9					4.0
Lowest mean temperature....	9.7	8.9	9.6	12.3	19.9	19.9	22.9	22.0	16.2	15.1	11.4	10.4					1.3
Absolute maximum temperature	—26.0	—22.5	—25.0	—21.0	—8.2	—2.0	0.8	—1.2	—4.7	—8.6	—17.9	—21.1					22.9
Absolute minimum temperature	0.6	0.1	0.6	3.4	7.2	11.1	12.7	12.0	9.7	5.7	2.9	1.0					—26.0
Mean minimum temperature..	—5.0	—5.5	—5.3	—2.1	1.6	5.5	7.3	6.7	4.7	1.0	—2.0	—4.3					
<b>Vestmannaeyjar</b>																	
From $\frac{1}{7}$ 1877 to $\frac{31}{12}$ 1906.	1.3	1.3	1.4	4.0	6.3	9.0	10.6	10.2	8.2	5.1	3.0	1.2	1.3	3.9	9.9	5.4	5.1
Mean temperature.....	3.2	3.7	5.4	6.5	8.7	10.4	12.7	12.3	9.9	7.3	5.6	3.6					5.9
Highest mean temperature....	—1.7	—2.4	—3.0	—2.4	4.0	7.2	9.1	9.0	6.3	2.7	0.4	—3.2					4.1
Lowest mean temperature....	9.7	10.4	10.6	12.4	16.1	21.2	19.6	18.5	16.4	13.1	10.9	10.0					21.2
Absolute maximum temperature	—17.4	—15.2	—20.9	—13.3	—9.5	—0.8	2.7	0.3	—2.6	—6.6	—16.1	—16.0					—20.9
Absolute minimum temperature	3.8	3.9	4.3	6.9	9.8	12.7	14.1	13.8	10.8	7.3	5.4	4.0					
Mean maximum temperature..	—1.8	—1.8	—1.6	1.1	3.8	6.8	8.2	7.6	5.8	2.2	0.3	—1.5					
Mean minimum temperature..																	
<b>Berufjörður</b>																	
From $\frac{1}{12}$ 1872 to $\frac{31}{12}$ 1906.	—1.3	—1.3	—1.5	1.3	4.0	7.2	8.7	8.3	6.8	3.2	0.9	—0.7	—1.1	1.3	8.1	3.6	3.0
Mean temperature.....	1.6	1.9	2.4	5.2	7.1	9.4	10.3	10.7	8.9	5.3	3.6	2.1					4.2
Highest mean temperature....	—8.5	—5.7	—9.4	—3.3	1.7	4.7	6.4	6.1	4.6	0.6	—2.4	—6.7					1.0
Lowest mean temperature....	13.2	12.3	12.2	14.9	20.4	25.4	26.3	23.5	20.5	16.4	12.4	11.5					26.3
Absolute maximum temperature	—23.1	—19.3	—21.9	—18.3	—10.8	—4.2	0.8	—2.9	—5.8	—10.3	—17.4	—20.4					—23.1
Absolute minimum temperature	1.7	1.6	1.6	4.4	7.8	11.3	12.8	11.9	9.7	5.6	3.4	1.9					
Mean maximum temperature..	—4.1	—4.2	—4.9	—1.7	1.1	4.1	5.9	5.5	4.2	0.7	—1.8	—3.5					
Mean minimum temperature..																	
<b>Papey</b>																	
From $\frac{1}{18}$ 1873 to $\frac{31}{12}$ 1906.	—0.9	—1.2	—1.7	0.5	2.7	5.4	6.8	7.0	6.0	3.1	1.1	—0.4	—0.8	0.5	6.4	3.4	2.4
Mean temperature.....	1.7	2.0	2.4	4.7	4.9	7.5	8.5	9.6	7.9	5.1	3.4	2.1					3.7
Highest mean temperature....	—8.3	—5.3	—8.8	—3.1	0.2	3.0	4.5	4.2	3.8	0.2	—2.2	—6.4					0.1
Lowest mean temperature....																	
<b>Grimsby</b>																	
From $\frac{1}{7}$ 1873 to $\frac{31}{12}$ 1906.	—2.0	—3.0	—3.6	—1.2	1.7	5.5	7.0	6.8	5.7	2.5	0.0	—1.3	—2.1	—1.0	6.4	2.7	1.5
Mean temperature.....	1.6	1.2	1.4	3.3	5.1	8.5	10.1	10.8	8.5	4.7	2.8	2.1					3.1
Highest mean temperature....	—13.1	—10.7	—16.5	—7.1	—0.7	1.7	3.7	2.2	3.7	—0.3	—3.8	—9.0					—0.8
Lowest mean temperature....	9.5	8.8	9.6	10.8	16.0	21.0	19.6	26.2	18.3	12.9	11.2	9.9					26.2
Absolute maximum temperature	—30.0	—25.0	—30.0	—23.8	—12.2	—6.9	—3.0	—3.0	—5.0	—11.0	—17.5	—20.4					—30.0
Absolute minimum temperature	0.5	0.3	0.6	1.2	4.1	8.5	9.9	9.6	7.9	4.2	2.0	1.1					
Mean maximum temperature..	—4.8	—5.6	—6.0	—4.0	—0.5	3.0	4.8	4.7	3.1	0.3	—2.7	—4.1					
Mean minimum temperature..																	



sequence. As the rainfall, however, is often accompanied by storms, the weather is frequently very unpleasant for man and beast. It is especially in South Iceland that complaints are heard of the storms of sleet during autumn, when everything becomes saturated with moisture and rain penetrates into the houses through every chink and crevice. The humidity is more considerable in South than in North Iceland, which is shown for instance by the fact that houses with turf walls must be rebuilt more often in the southern districts. A cold, damp, whitish fog, accompanied by sleet, is very characteristic of the northern headlands, especially when the Greenland ice drifts backwards and forwards along the coast; then fog may shroud the coast for weeks and extend far into the valleys. The fog persists for a long time also in other places along the coast, especially in East Iceland. The amount of cloud also is generally great, especially in North Iceland.<sup>1</sup>

The amount of rainfall varies greatly in the different parts of Iceland, and in most places it is generally greatest during autumn and winter; on Grímsey, however, it is greatest during summer and autumn. The precipitation is greatest along the south and south-east coasts: in the Vestmannaeyjar 1320 mm., and at Berufjord 1166 mm. The greatest amount of annual rainfall in the Vestmannaeyjar was 1587 mm., and at Berufjord 1737 mm. Along the west coast the rainfall is much less, and still less in North Iceland, being at Stykkisholm 656 mm., but on Grímsey only 345 mm. At Stykkisholm there are, however, on an average 207 rainy days, but on Papey only 135, consequently, a much greater amount of rain falls there at a time. At Berufjord the greatest amount of rainfall within 24 hours was 109½ mm. (July); at Stykkisholm 51.9 mm. (January); and on Grímsey 34.3 mm. (November). Heavy showers and sudden torrents of rain do enormous damage to the soil-layer on the mountain-sides, which are usually woodless and unprotected, and occasion numerous rock-slips which have often proved very disastrous to property and human life. The frequency of fogs differs greatly at different parts of the coast, but it is most frequent along the southern part of the east coast where the warm and cold ocean currents meet. At Berufjord there are on an average 171 foggy days annually; here fogs are frequent at all the periods of the year, but they occur most frequently during summer. On Papey (in the neighbourhood

<sup>1</sup> Amount of cloud (0—10): Vestmannaeyjar 6.2; Stykkisholm 6.7; Berufjord 6.7; and Grímsey 8.3.

Table VII. Amount of Precipitation along the coast

	January	February	March	April	May	June
<b>Stykkishólmur</b>						
From $\frac{1}{6}$ 1873 to $\frac{31}{12}$ 1906.						
Mean precipitation .....	78.2	65.5	45.0	34.6	38.6	39.4
Highest amount for the month .....	184.0	217.2	116.6	67.0	132.0	104.8
Lowest amount for the month .....	17.5	6.0	10.7	4.2	2.0	10.7
Greatest amount of precipitation during 24 hours .....	51.9	50.1	19.2	17.6	19.8	19.8
Number of days with snow .....	16	14	13	8	3	0.4
— fog .....	0.3	0.5	0.4	0.7	2.0	1.3
— frost .....	26	25	26	19	9	1
— storm .....	6	6	6	4	4	2
— precipitation .....	21	19	18	16	15	15
<b>Vestmannaeyjar</b>						
From $\frac{1}{7}$ 1877 to $\frac{31}{12}$ 1906.						
Mean precipitation .....	133.6	108.5	110.2	92.1	77.9	86.1
Highest amount for the month .....	225.6	195.1	239.0	198.1	149.1	145.6
Lowest amount for the month .....	34.5	29.6	26.1	15.0	11.5	30.0
Greatest amount of precipitation during 24 hours .....	41.8	54.8	62.6	33.6	46.9	34.4
Number of days with snow .....	9	8	8	4	1	0.2
— fog .....	2	2	2	3	5	8
— frost .....	20	18	17	10	3	0.1
— storm .....	4	3	3	2	1	0.5
<b>Berufjörður</b>						
From $\frac{1}{12}$ 1872 to $\frac{31}{12}$ 1906.						
Mean precipitation .....	122.8	95.6	76.1	88.0	70.8	71.3
Highest amount for the month .....	258.7	214.9	231.6	222.9	237.6	168.2
Lowest amount for the month .....	26.6	4.6	2.6	15.0	0.0	17.9
Greatest amount of precipitation during 24 hours .....	57.2	59.0	62.6	44.8	52.6	108.1
Number of days with snow .....	8	8	9	5	3	0.4
— fog .....	11	11	11	14	17	19
— frost .....	24	22	25	18	10	2
<b>Papey</b>						
From $\frac{1}{8}$ 1873 to $\frac{31}{12}$ 1906.						
Number of days with precipitation .....	14	13	12	12	9	8
— snow .....	7	7	7	5	3	0.5
— fog .....	9	9	10	12	13	16
<b>Grímsey</b>						
From $\frac{1}{7}$ 1873 to $\frac{31}{12}$ 1906.						
Mean precipitation .....	21.5	22.2	22.5	15.9	19.3	21.8
Highest amount for the month .....	58.0	112.0	73.8	37.5	98.7	59.0
Lowest amount for the month .....	1.2	0.6	2.4	1.2	3.0	3.2
Greatest amount of precipitation during 24 hours .....	16.5	20.4	13.8	16.1	28.1	21.4
Number of days with snow .....	7	8	8	7	5	2
— fog .....	1	1	2	4	6	7
— frost .....	25	24	27	24	17	5
— storm .....	2	1	1	0.3	0.2	0.4

of Iceland in millimetres for the Period 1872—1906.

July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for year
38.0	39.2	72.7	71.5	69.6	63.6	207.3	118.2	116.6	213.8	655.9
90.4	129.6	149.3	152.2	126.7	125.5					
4.9	3.2	20.1	19.4	20.4	11.7					
19.1	24.4	50.5	31.8	34.4	23.6					
0.1		1	4	10	14	44	24	1	15	84
1.6	1.3	0.7	0.3	0.4	0.3	1	3	4	1	9
	0.1	1	13	20	26	77	54	1	34	166
1	2	4	5	5	5	17	14	5	14	50
14	14	18	18	19	20	60	49	43	55	207
81.6	77.9	142.6	135.5	132.2	141.4	383.5	280.2	245.6	410.3	1319.6
153.2	226.7	215.9	241.2	244.0	296.1					1586.8
10.1	13.2	48.3	61.7	50.9	50.6					946.4
49.5	51.4	54.8	59.4	58.0	41.4					62.6
		0.3	2	4	8	25	13	0.2	6	44
8	6	5	4	2	2	6	10	22	11	49
	0.4	1	8	13	19	57	30	0.1	22	109
0.3	0.3	2	2	3	4	11	6	1	7	25
69.3	79.2	128.0	118.0	113.9	132.8	351.2	234.9	219.8	359.9	1165.8
180.9	225.5	314.4	267.7	245.9	331.4					1737.1
0.7	8.1	6.1	9.7	9.3	1.8					571.5
109.5	64.5	72.5	55.9	56.2	83.4					109.5
	0.1	0.5	3	6	7	23	17	0.5	9.5	50
21	18	16	12	11	10	32	42	58	39	171
	0.3	2	13	18	24	70	53	2	33	158
8	8	11	12	14	14	41	33	24	37	135
0.1		1	3	5	6	20	15	1	9	45
17	16	12	11	10	8	26	35	49	33	143
34.5	38.8	41.7	44.7	36.8	24.9	68.6	57.7	95.1	123.2	344.6
128.5	139.0	75.0	185.9	154.0	66.9					
1.2	0.8	7.4	13.4	4.2	0.0					
19.9	20.2	32.0	32.3	34.3	17.6					
0.5	0.4	2	6	9	9	24	20	3	17	64
10	8	4	2	0.5	0.3	2	12	25	6	46
2	2	4	17	21	24	73	68	9	42	192
0.2	0.2	1	1	2	2	5	1.5	0.8	4	11

of Berufjord) there are 143 foggy days. In other places fogs are much rarer; for instance on Grímsey there are on an average 46 foggy days, the majority of which occur during summer, while at Stykkisholm there are only nine. Along Hornstrandir fogs are very common especially during ice-years, but from this locality no observations are to hand.

The amount of snow varies greatly according to situation and height above sea-level, and from year to year. In North Iceland snow often persists for a long time during winter, but in south-west Iceland the weather is always stormy and unsettled; consequently, in the lowlands the winter-snow rarely persists for a long time. Frost and thaw often alternate daily. In South Iceland it often happens during winter that no snow is to be seen for months in the lowlands. On the other hand, it rains very often, and the precipitation which falls here as rain, produces on the plateau considerable masses of snow. By way of exemplifying the durability of the snow-covering, I give the results of my observations — the number of days with snow-covering — in Reykjavík during the winters of 1889—1892 and 1893—1895 in the following table: —

	1889—90	1890—91	1891—92	1893—94	1894—95
September.....	0	0	0	2	0
October.....	2	4	1	2	1
November.....	9	10	10	5	2
December.....	23	12	26	27	23
January.....	31	13	25	14	18
February.....	15	13	29	28	3
March.....	16	30	24	14	8
April.....	0	2	6	0	5
	96	84	121	92	60

In these five winters it snowed for the first time on Oct. 28, Sept. 28, Oct. 24, Sept. 19 and Oct. 31 respectively; for the last time on March 20, April 18, April 26, March 30 and April 18. Very often the snow persisted for a day or two only. The longest period during which the ground was covered continually with snow, was in the winter of 1891—92, viz. 63 days, from Jan. 19 to March 21. In all these winters the neighbouring Akrafjall, which has an altitude of 364 metres was often entirely snowless. In several places in North



Iceland the snow-covering persists so long during winter, that all intercourse between the farmsteads takes place on snow-shoes, and goods are transported on sledges, but in South Iceland sledges are hardly ever seen and still less snow-shoes. Snow may fall in any of the summer months, but in South Iceland it is only rarely that there is snowfall of any consequence during summer. In the northernmost districts it happens now and then, especially when Polar ice is in the vicinity of the island, that it snows so heavily for some days during mid-summer, that haymaking is suspended and the cattle must be stabled for a shorter or longer time. On the plateau snow-storms accompanied with frost occur now and then in July and August, and upon the great ice-mountains (Jökulls) it often snows in all months of the year. During a period of 30 years it snowed on an average 84 days annually at Stykkisholm, 44 days in the Vestmannaeyjar, 50 days at Berufjord, 45 days on Papey and 64 days on Grímsey. The amount of snow, as already mentioned, varies greatly according to the year. Snow-storms during winter have often caused great disasters by destroying thousands of sheep and many human lives. The annals of Iceland give us much information of such disasters, and numerous written records of many centuries show that the climate of Iceland has not changed since its first colonization in the year 874.

Hail is fairly common during winter, but rare during summer. On Grímsey it hails about twenty-four times annually; in the Vestmannaeyjar twenty times, at Stykkisholm five times and on Papey twice. The hail-stones are as a rule small, rarely larger than grit; but during volcanic eruptions, they are much larger, and often include grains of volcanic sand or ashes. Thunder is very rare and occurs as a rule only in winter. The registered thunderstorms average two in the year in the Vestmannaeyjar, and only one at Stykkisholm and Berufjord, while none have ever been registered on Grímsey. On the whole, thunderstorms are extremely rare in northern Iceland; thus at Audkula vicarage, in the district of Húnavatnssýsla, thunder was heard once only between 1857 and 1873. Thunderstorms are more common along the southernmost part of the coast (Eyjafjöll, Landeyjar, Rangárvellir) where they occur sometimes during the summer also. The volcanic eruptions are almost always accompanied by thunder and strong electrical discharges.

The climatic conditions we have hitherto been considering, have naturally been those connected especially with the coasts and the



inhabited districts, because there alone permanent meteorological stations are found. The climate of the uninhabited plateau is far less known. Although it is possible, from the climate at the coast, to draw fairly definite conclusions as regards the climate of the interior, derived from the height above sea-level and the distance from the coast, yet almost all accurate investigations and observations from the plateau are wanting. The only climatological station on the plateau is Möðrudalur (469 metres above sea-level), and it will be seen that the climate there is far more severe than at the coast (see Table IV), from which again may be concluded how very severe must be the winter up at the Jökulls in the centre of the island, at a height of 1000—1400 metres; the climate in the interior is certainly far more continental than at the coast. The winter in Möðrudalur (mean temperature  $-7.2^{\circ}$  C.) is almost twice as severe as in the inhabited districts of North Iceland at any height up to 100 metres above sea-level, with a mean temperature of  $-3.5^{\circ}$  C. The spring of Möðrudalur is very cold with a mean temperature of  $-2.1^{\circ}$  C., and the mean autumn temperature is also below zero ( $-0.7^{\circ}$  C.), but the summer is as warm as at the coast. On Odádahraun and north of Arnarfellsjökull the winter is beyond doubt very severe, with perhaps a mean temperature of  $-10^{\circ}$  or less. That the frost persists for a long time is seen by a few small oases, where the snow does not thaw until during July and where a miserable vegetation appears only for a period of two months. On the plateau the storms blow with great force, driving sand, gravel and small rock-fragments across the desolate plains and ridges of rock, thereby striating and polishing them; as mentioned above, the wind also carries great quantities of tuff-dust and blown sand from the plateau down to the valleys and lowlands. During summer it may sometimes become fairly warm in the middle of the day, but, in the interior of the plateau, it usually freezes during the night, so that small water-courses and pools of water are ice-covered early in the morning. Snow-storms occur now and then, and sand- and rain-storms and fogs are very common. The large Jökull-domes in the centre of the plateau often appear to form a climatic boundary, the weather frequently being opposite in character to the north and south of them. Thus, there is often bright sunshine on Arnarvatnsheiði, north of Langjökull, while south-easterly storms of rain are raging over the plateau south of the same Jökull; conversely it may be warm sunshiny weather on the

southern side, while fogs, with sleet and cold, extend from Húnaflói to the plateaus north of Langjökull. In a similar manner the mountain ranges on Reykjanes and Snæfellsnes exert great influence upon the local weather-conditions in the districts on either side of them. Apart from this, the weather often varies greatly in the different parts of the coast — a storm may be blowing on the south coast, while it is calm on the north coast. Northerly winds usually bring snow or rain to North Iceland, while they bring clear weather upon the south coast; southerly winds bring rain or snow-squalls to South Iceland and almost always an overcast sky, while simultaneously it is clear weather in North Iceland. The weather may differ in the fjords: a storm may be blowing out of the fjord, while it is calm outside, and vice versa. Sudden and strong gusts of wind blowing down from the mountains are often dangerous in some fjords, and in mountainous districts, highly intersected by valleys and ravines, the conditions of weather in the different districts are very capricious. On the whole, the weather-conditions on Iceland are very variable and unreliable in character.

#### IV. ACCOUNT OF THE GENERAL DISTRIBUTION OF PLANT-LIFE.

**I**n connection with the description of the physiographical and climatic conditions, I shall now try to give a very brief account of the distribution of plant-life on the rocky substratum of Iceland. The following should be regarded merely as an attempt towards a description of the main features for general orientation. It is expected that later on in this work a more accurate and detailed account of the plant-geographical conditions will be given, and the ecological conditions and the different plant-formations will be described and analysed by different specialists.

Geological investigation has proved that Iceland in early Tertiary times was in all probability connected with Greenland and with Scotland across the Færøes by a land-bridge of volcanic, especially basaltic, rocks; the depression of this land-bridge had probably occurred and the countries been separated even in the Miocene period. During Pliocene times Iceland was somewhat larger than it is now, but subsidence continued; during this period the submarine coastal platform was formed, which occurs around the whole island, and also the now submarine fjord-grooves which lead off from the mouths of the present-day fjords. At the end of Pliocene times the climate gradually became colder until the Glacial period laid a continuous snow-covering over the whole island. Some botanists are of the opinion that a land-bridge connected Iceland and the Færøes with Greenland and Scotland during post-Glacial times also, but this hypothesis is highly improbable as it is at variance with many geographical and geological facts which are enumerated in the works cited below.<sup>1</sup> No geologist who is closely acquainted with the

<sup>1</sup> Th. Thoroddsen: Hypothesen om en postglacial Landbro over Island og Færoerne, set fra et geologisk Synspunkt, Ymer, Stockholm, 1904, pp. 392—399. Endnu nogle Ord om Landbro-Hypothesen, Ymer, 1906, pp. 93—101. Naturwissenschaftliche Rundschau, XXI Jahrg., No. 31. Island. Grundriss der Geologie und

geology of Iceland has been able to find any support for this hypothesis.

The Tertiary vegetation — probably from Eocene and Miocene times — which, as already mentioned, is found in the clay beds and in the so-called “Surtarbrand” in the middle of the basalt formation, was probably much altered in character even in Pliocene times, but unfortunately from this period there has as yet been found only a few small and undeterminable fragments of plants (conifers). When the Glacial period buried Iceland beneath an icy covering the Tertiary flora died out entirely, and the present flora must consequently have immigrated after the Glacial period and perhaps even partially during it, in intervening milder periods when the glaciers retreated slightly. As yet there are no real proofs to hand of an interglacial period in Iceland when the country was entirely free from ice and partially plant-covered.

As already mentioned, only a very small part of Iceland is really plant-covered. The continuous carpets of vegetation are only of slight extent compared with the considerable area of the island, and even in low-lying, inhabited districts large areas are occupied by rocky flats, *Grimmia*-heaths, sandy stretches poor in plant-life, lava-streams, etc. This is of course primarily due to the northerly situation of the island and the climatic conditions. The climatological chapter shows that the climate of Iceland is raw and cold. The winter is long, but generally not very severe; the summer is comparatively short and cold and the weather is usually changeable and damp; during spring, cold winds and sea ice accompanied by fogs do great damage as they often occur in the beginning of the growth-period. In many places the plants — many of which are evergreens — are protected from the cold of winter by a lasting snow-covering, but, as we have seen in the above, in several districts, especially in South Iceland, this snow-covering is variable and of short duration so that plant-growth suffers greatly under the influence of the cold wind; it is easily seen that there is great difference in the vegetation of the bare gravelly flats where the snow drifts off and of the depressions and localities in the shelter of rocks where the snow persists. Differences in the temperature and weather conditions of the different years according to whether Polar ice visits the coast or not, are of the greatest importance to plant-life.

The snow-coverings in the lowlands generally melt away in April and the period of growth begins in May. But the time for the appearance of the plants differs considerably throughout the extent of the island, not only according to position and height above sea-level, but also on account of the conditions of weather in different years.

In south-west Iceland, in the neighbourhood of Reykjavík, in somewhat favourable years a few species flower at the end of April, e. g. *Saxifraga oppositifolia* and *Arabis petraea*, but in the beginning of May a great many plants are in bloom, e. g. *Salix herbacea*, *Alchimilla alpina*, *A. vulgaris*, *Draba incana* and *Silene acaulis*, somewhat later and until the middle of the month *Caltha palustris*, *Cardamine pratensis*, *Armeria maritima*, *Rumex acetosa*, *Oxyria digyna* and at the end of the month *Ranunculus acer*, *Taraxacum vulgare*, *Cerastium alpinum*, *C. vulgare*, *Thalictrum alpinum*, *Arctostaphylos uva ursi*, *Pinguicula vulgaris*, *Betula nana* and others. The common flowering period begins in June; and June and July are the months richest in flowers. For the rest, the flowering period is highly dependent on the weather; it may be delayed in colder years, especially in ice-years, but on the other hand, during prolonged periods of thaw in winter some flowers may open in February and March. On the northernmost points of land and on the plateau the time for flowering is naturally somewhat later.<sup>1</sup>

The number of plant-species found in Iceland cannot yet be stated with any certainty, but later in this work the lists and collections will be critically investigated and new species added to the list.<sup>2</sup> The number of species of known phanerogams and vascular

<sup>1</sup> For observations regarding the time of flowering in East Iceland in 1893 and 1894 see Helgi Jónsson: Vinter- og Vaar-Ekskursioner i Øst-Island (Botanisk Tidsskrift, 1895, pp. 274—275 and 292—294), and in the neighbourhood of Reykjavík in 1873—1875 see Th. Thoroddsen's notes in Grönlund's Karakteristik af Plantevæksten paa Island, pp. 17—18. Moreover, there are some notes on the subject which have not as yet been published; but they make no difference as regards the general sketch of the spring-flowering given here.

<sup>2</sup> The chief floristic works on Iceland are the following: — St. Stefánsson: Flóra Islands, København, 1901. W. Lauder Lindsay: Flora of Iceland. (New Philosophical Journal, New Series, Edinburgh, July, 1861; 40 pages). C. C. Babington: A Revision of the Flora of Iceland. (The Journal of the Linnean Society, Vol. XI, London, 1871, pp. 282—348). Chr. Grönlund: Bidrag til Oplysning om Islands Flora. Højere Kryptogamer og Phanerogamer. (Botanisk Tidsskrift, 2. Række, IV, 1874, pp. 36—85). Chr. Grönlund: Islands Flora. København, 1881. Chr. Grönlund: Afsluttende Bidrag til Oplysning om Islands Flora. (Bot. Tidsskr., XIV, 1885, pp. 159—217). H. F. G. Strömfelt: Islands kärlväxter. (Öfversikt af Kgl. Vetensk.



cryptogams may, I think, be estimated at 400—450. Chr. Grönlund in 1884 enumerated 366 species ( $340 + 26$ ); E. Rostrup in 1887, 409 species ( $381 + 28$ ); E. Warming in 1888, 417 ( $388 + 29$ ); St. Stefánsson in 1890, 423 species ( $395 + 28$ ), but in "Islands Flora," 1901, only 359 species; Helgi Jónsson recorded in 1896, 435 species, but in 1904, 360 species. It is thus seen that the number of the species differs somewhat according to the different authors; the reason for this I shall not enter into more closely here. For comparison it may be mentioned that the number of species known from the Færøes (Ostenfeld, Botany of the Færøes) is about 300 species of phanerogams and vascular cryptogams, from Greenland (E. Warming, 1888) 386 species, from Denmark about 1450 species, from Norway 1500. In the following I give an account for comparison and orientation; it is based on E. Warming's statistics (1888) and gives an excellent general idea of the subject, but it will probably be somewhat modified in its details on a later revision of the material. Warming records, according to what was known at that time of the flora of the island, that of circumpolar species there were found in Iceland 64, in Greenland 96 and in the Færøes 36; of sub-boreal and sub-alpine species in Iceland 70, in Greenland 87 and in the Færøes 33; and of temperate zonal species in Iceland 151, in Greenland 82 and in the Færøes 134. Of species which occur both in Europe and in America 48 are found in Iceland, 16 in Greenland, 47 in the Færøes; of those common to America, Europe and Spitzbergen 3 are found in Iceland, 5 in Greenland, 2 in the Færøes; in common with America alone Iceland has two species only, Greenland 21 and the Færøes none; in common with Europe there occur in Iceland 42, in Greenland 19 and in the Færøes 54 species. Greenland has 222 species in common with Iceland, but 137 with the Færøes; on the other hand, Iceland and the Færøes

Akad. Förhandlingar. Stockholm, 1884, pp. 79—124). E. Rostrup: Bidrag til Islands Flora. (Bot. Tidsskrift, XVI, 1888, pp. 168—186). Stefán Stefánsson: Fra Islands Væxtrige, I—III. (Vidensk. Meddelelser fra Naturh. Foren. i København. 1890, pp. 166—181; 1894, pp. 174—212; 1896, pp. 118—153). O. Gelert og C. Ostenfeld: Nogle Bidrag til Islands Flora. (Botan. Tidsskrift, XXI, 1898, pp. 339—348). Helgi Jónsson: Bidrag til Ost-Islands Flora. (Bot. Tidsskr., XX, 1896, pp. 327—357). Helgi Jónsson: Floraen paa Snæfellsnes og Omegn. (Bot. Tidsskr., XXII, 1899, pp. 169—207). Helgi Jónsson: Liste over Karkryptogamer og Phanerogamer i Syd-Island. (Bot. Tidsskr., XXVII, 1905, pp. 62—82). As regards older botanical literature, see Bibliogr. in E. Warming: Den danske botaniske Literatur fra de ældste Tider til 1880 (Botanisk Tidsskrift, XII, pp. 42—131, 158—247) and in Th. Thorodd-sen: "Landfrædissaga Islands," Vol. 4, Copenhagen, 1904.

have 237 species in common. Of the higher plants in Iceland the majority of the species belong to the Cyperaceæ (44) and the Gramineæ (40), and these two families are also most characteristic of the inhabited land and of the greatest importance as regards the sustenance of the inhabitants. Of Compositæ there are 25 species, of Caryophyllaceæ 24, Cruciferæ 22, Juncaceæ 17, Filices 17, Rosaceæ 16, Scrophulariaceæ 13, Papilionaceæ 12, etc.<sup>1</sup> The lower plants have not yet been closely investigated; there are known, however, 300 species of mosses, 233 species of lichens and 543 species of fungi, 452 of which are parasites; on *Betula odorata* have been found 54 species of parasites, on *Salix lanata* 14 species, on *Dryas octopetala* 11, and on *Betula nana* and *Salix glauca* 10, etc. The mushrooms, of which many occur, are as yet but slightly known.<sup>2</sup>

Naturally, nothing is known as to how many species have immigrated into Iceland since the first colonization of the island in 874, but we may take for granted that the number is considerable. Even by the first "Landnámsmen" several species were undoubtedly imported from Norway and perhaps also from the islands along Scotland. In the Sagas we read about live-stock (cows, horses, sheep and swine) being brought to Iceland and in the fodder brought along with them there were certainly several foreign seeds. Some of the immigrants for religious reasons, brought earth with them from Norway from the site of their former temple (Hof). Then the settlers also used foreign seed for cereal crops, on the cultivation of which they were very keen at first. Moreover, different species may have been introduced along with articles of commerce and in other ways. Of imported species, which during later centuries have gained a firm footing and have become naturalized, the most common are *Urtica urens*, *U. dioeca*, *Cirsium arvense*, *Spergula arvensis*, *Carum carvi*, *Lamium intermedium*, *Senecio vulgaris* and some others.

<sup>1</sup> Eug. Warming: Tabellarisk Oversigt over Grönlands, Islands og Færøernes Flora, 1887. (Vidensk. Meddel. fra den naturhist. Foren., 1887. Köbenhavn, 1888).

<sup>2</sup> Chr. Grönlund: Islandske Naturforhold med særligt Hensyn til Mosvæxtens Betydning for Landskabet (Tidsskrift for populære Fremstillinger af Naturvidenskaben. 5. Række, IV, 1877, pp. 321—356). Bidrag til Oplysning om Islands Flora, Lichenes, Hepaticæ og Musci (Bot. Tidsskr., IV, 1870, pp. 147—172; 2. Række, III, 1873, pp. 1—26). Afsluttende Bidrag til Oplysning om Islands Flora, Musci, Hepaticæ, Lichenes (Bot. Tidsskr., XIV, 1885, pp. 159—217). Tillæg til Islands Kryptogamflora, indeholdende Lichenes, Hepaticæ og Musci (Bot. Tidsskr., XX, 1895, pp. 90—115). Islandske Svampe samlede 1876 af Chr. Grönlund (Bot. Tidsskr., XI, 1879—80, pp. 72—76). E. Rostrup: Islands Svampe (Bot. Tidsskr., XIV, 1885, pp. 218—229; XXV, 1903, pp. 281—335).

Lastly some 40—50 foreign species have been found which have not yet gained a permanent footing in the flora, some of which will probably again disappear.

There can be no doubt that the vegetation has been modified in various ways since man with his cattle-rearing came upon the scene; sheep have especially exerted a great influence upon the coppice-woods and other vegetation; in the few places to which sheep cannot gain access, e. g. in distant valleys surrounded by glaciers and rivers of great volume, on islands in the middle of waterfalls or torrential rivers or in lakes the vegetation is usually far more luxuriant than in other places. In Viðidalur in Lón I had the opportunity of noting an example of the change effected by sheep-rearing. The locality in question is situated 439 metres above sea-level and has a southern exposure; it is surrounded by glaciers and deep river-gorges impossible for sheep and cattle to cross. Formerly the valley had been inhabited for a short time, but in 1840 it was deserted by the inhabitants. I visited the valley in the cold summer of 1882 and found there a very luxuriant vegetation; all the plants had a height quite unusual in Iceland. At the bottom of the valley the grass and the different species of willow usually reached to the horse's belly; especially were *Salix phylicifolia*, *Geranium silvaticum*, *Bartsia alpina* and *Archangelica officinalis* of considerable size; there was almost a wood of *Archangelica* which reached a height of 1—2 metres. The old ruins of the huts which were destroyed in 1840 by an avalanche were overgrown with *Archangelica officinalis* and *Salix phylicifolia*, and from the old fire-place a willow, belonging to the latter species, had grown out, about 2 metres in height, with stem 3—4 cm. in diameter. In 1883 the valley was again inhabited. I revisited the place in the summer of 1894 and found the conditions greatly changed owing to cultivation and the influence of sheep and cattle. That tract of land upon which the above-mentioned species had reached their highest development was now laid out as a manured home-field (tun), overgrown by species of grass characteristic of manured fields. These grasses had not, however, yet gained mastery over the wild vegetation; the single plants of grass stood far apart, so that the field only yielded 64 cwt. hay per annum, while in the coastal districts a well cultivated field of the same size would have yielded 240 cwt. Besides, the soil was quite intersected by subterranean portions of former plants, roots of willows, etc. This vegetation would therefore in all probability quickly become

predominant if the farm were to be abandoned. Small willow-shrubs (*Salix phylicifolia* and *S. glauca*) had grown out from several pieces of turf which had been used for making the walls of the houses. On account of the large number of sheep the plant-growth of the whole valley had degenerated. The luxuriance had entirely disappeared; no plants of any height were to be seen, the willow shrubs had become smaller and flatter in growth, as during winter the sheep nibble off the uppermost shoots which protrude through the snow; here it had not been possible to procure sufficient hay for winter-fodder, therefore, during winter the sheep had been left to shift for themselves with the result that they had attacked the willow coppices and a neighbouring birch coppice in Kollumuli.

But the destruction of the coppice-woods has exerted the greatest influence upon the vegetation. The Icelandic author Ari fródi (born 1067) says in his "Íslendingabók" that when the first settlers came to Iceland it was wooded from the sea to the mountains or inner plateau ("milli fjalls ok fjöru"). But this statement is doubtless due to exaggeration. Arngrímur, the Abbot of Thingeyrar, writes in 1350 about Iceland "woods do not occur except birch, and that is low in growth." At the first colonization of Iceland many mountain-sides were probably coppice-clad right to the verge, likewise many ridges, gravelly stretches and old lavas on the plains, which are now bare. The coppices spread over a great part of the coastal districts and the valleys, but nowhere extended up on the plateau above a height of 600 metres, and probably even at that time the northern peninsulas and the extreme points of land were woodless. In the lowlands also many tracts of sand, bogs and new lavas were undoubtedly bare of wood as in the present time, and probably not more than 4000—5000 square km were covered with coppice at the beginning of the 10th century. The birch stems found in the bogs also show that the trees of olden times were not larger than those now found in the best preserved patches of wood. From the Sagas it can be seen that even during the first centuries the woods had suffered greatly. Space was cleared for farms and home-fields, and the best stems were used as laths for the support of the turf-roofs, etc., of smaller houses, although the greater part of the building-wood was imported from Norway, at any rate in districts where there was not easy access to drift-wood which at that time was found in quantities along the northernmost coasts. Moreover, trees were recklessly felled for fuel and in addition, wood in olden times



was largely used for the smelting of bog iron-ore and for charcoal for smith's work. Even as late as 1870 charcoal was used in every farmstead during hay-making for the purpose of beating out and sharpening the scythes. Numerous remains of ancient charcoal-pits are still to be seen in many places where no woods are found today. Burning woods are several times mentioned in the Sagas. They were set on fire either accidentally or also maliciously for revenge or out of mischief. But for centuries the sheep and goats have been the worst enemies of the woods; during winter when the snow is lying on the ground they procure their means of sustenance chiefly from the woods, nibbling off all the buds and gnawing the branches and stems. Even in the middle of the 13th century the greater part of the woods had disappeared from the inhabited districts, and the remnants have since that time been gradually diminishing. It is a wonder that woods still exist in Iceland to such an extent that, including shrubs, they cover an area of about 454 square km.<sup>1</sup> In the beginning of the 15th century all the coppice-woods had disappeared from Hunavatns and Skagafjardarsyslur, but in Eyjafjardarsysla some remains of woodland persisted till the beginning of the 19th century. Now the whole stretch of land from Eyjafjörður to Hrutafjörður is devoid of wood. Even in the middle of the 18th century woods, fairly high in growth, existed in several places from which they have now disappeared; they were greatly damaged by the Katla and Laki eruptions of 1755 and 1783 respectively.

Generally speaking, it may be said that the same kind of vegetation prevails throughout the island; taken as a whole, there is no great difference between north and south, high and low. The character of the flora is the same everywhere, although on a closer inspection it will be seen that the composition of the plant-formations varies somewhat, and that certain species are peculiar to, or specially common in, certain districts. The different species vary extremely as regards the number of their individuals; true, the largest areas are covered with a continuous carpet of grasses, sedges, dwarf-willows, heathers and *Grimmias*, but some species characteristic of rocky flats, such as *Armeria maritima*, *Polygonum viviparum*, *Cerastium alpinum*, *Salix herbacea*, *Silene maritima*, *Oxyria digyna*, *Sibbaldia procumbens* and others, occur widely distributed as scattered individuals throughout the island from the coast to the snow-line. Ac-

<sup>1</sup> Landshagsskýrslur fyrir Island, 1911, Reykjavík, 1912. p. 89.



cording to St. Stefansson's "Flora Islands," where 359 species are described, 197 species are common all over the island, 37 common in a few districts, 72 species are rather rare, and 53 species very rare.

As already mentioned, the vegetation has a homogeneous character throughout the island, and — according to our present knowledge — there are only a few species which are especially characteristic of certain parts of the island. East Iceland (Múlassýslur) is most noticeable in this respect; also, plant-geographically, Austur-Skaftafellssýsla, which stretches as a narrow ribbon along the southern edge of Vatnajökull as far as to Skeidarársandur; this extensive sandy tract forms a limit for several of the eastern species. *Campanula rotundifolia* is a common characteristic plant in East Iceland, but very rarely so in other places; I found the most westerly individuals of this species on Brunasandur towards the southwest, and at Hólkná in the district of Thistilfjord towards the north, but it is very common east of these boundaries. *Saxifraga aizoides* is very common in East Iceland, but has not been found elsewhere — I found it in a most south-westerly direction at Øræfi and in a most north-westerly direction near Vidirhóll at Fjallasveit. *Trientalis europea* grows in various places in the coppice-woods of East Iceland, but nowhere else; *Alchimilla færoënsis* is also common in East Iceland, but has not been found elsewhere. *Cerastium Edmondstonii* has been found in some places in East Iceland and in one locality in Skaftafellssýsla. *Saxifraga Cotyledon* grows along the south-eastern coast from Foss in Sida to Eskifjord, and two species of rose, *Rosa pimpinellifolia* and *R. canina*, grow along the same stretch of coast and nowhere else; the former was found in three habitats, westernmost at Seljaland and easternmost at Reydarfjord; the latter was found only at Tvísker on Breidamerkursandur. *Lychnis flos cuculi* grows along the south coast from Eyjafjöll to Øræfi and has not been found in other districts.

In South and South-west Iceland several species are common which either are not found or are very rare in other districts. *Spiræa ulmaria* is common from Borgarfjord to Lónsheidi, rare in other places, and not found in Múlassýslur; *Brunella vulgaris* is very common in South Iceland, but very rare in other places; *Plantago lanceolata* is also common in South Iceland, but has otherwise been found only in a few places in North Iceland near hot springs. *Succisa pratensis* is characteristic of South Iceland and is especially common in Vestur-Skaftafellssýsla, west of Brunasandur. *Valeriana*

*officinalis*, *Vicia sepium*, *Galeopsis Tetrahit* and *Sanguisorba officinalis* occur only in southern and south-western Iceland. *Anthyllis vulneraria* is fairly common in south-west Iceland, but has otherwise been found only in one place in East Iceland (Njardvik); *Cakile maritima* is common in the sea-sand in south-west Iceland and in the southern part of the north-western peninsula, but has not been found elsewhere. *Lathyrus paluster*, *L. pratensis* and *Veronica anagallis* have been found only in south-west Iceland, and *Haloscias scolicum*, also, does not grow in other places with the exception of the islands in Breiðfjörður where it occurs rather frequently, and on the islands in Hornafjörður; *Hydrocotyle vulgaris* occurs near hot springs in South Iceland, especially in the district of Borgarfjörður, but has not been found elsewhere; *Zostera marina* is very common in south-west Iceland, but is rare in other places.

The plant life of the north-western peninsula is as a rule poor in species and not very characteristic. *Fragaria vesca* has not been found there, although it is fairly common all over the island; *Cornus suecica* grows in some places in Vestfirðir and near Breiðfjörður, but has not been found elsewhere, and *Melampyrum silvaticum* has been found only in wooded valleys near Isafjörður. *Papaver nudicaule* appears to be more common on the north-western peninsula than in other parts of the island. In North Iceland only a few characteristic plants occur. *Pleurogyne rotata* is, however, very common in North Iceland, but rather rare in other places; *Milium effusum* also is especially characteristic of the northern districts. *Phyllodoce coerulea*, which is so common in Greenland, is also fairly common on the northern mountainous peninsulas on either side of Eyjafjörður westwards as far as Fljótt, but has not been found elsewhere; *Primula stricta* has been found only near Eyjafjörður, and *Antennaria alpina* and *Erigeron uniflorus* have been found only on mountains in North Iceland.

Moreover, it may be mentioned that, here and there, a few otherwise rather rare species, by occurring in great abundance in certain localities, give a characteristic appearance to the landscape. Thus, in Selvogur *Anthyllis vulneraria* occurs so abundantly that during the flowering period large tracts are quite yellow; in Eyjafjörður and in Hrappsey considerable areas are closely covered with *Viola tricolor*. In Tröstansfjörður the whole strand is densely overgrown with *Cakile maritima*, which, although rather common in western Iceland, occurs nowhere so abundantly as here. An

unusually large quantity of *Viscaria alpina* grows at Ulfsvatn (400 metres above sea-level). An old lava-stream, south of Krakatindur and NE. of Hekla is almost exclusively overgrown with *Oxyria digyna*, which otherwise occurs rather rarely on lava. The neighbourhood of Eyjafjörður is characterized by a great abundance of *Gentiana*, and the neighbourhood of Lake Myvatn by its rich vegetation of *Nasturtium palustre* and *Pleurogyne rotata*; *Erysimum hieracifolium*, which is otherwise rather rare, occurs abundantly and as large specimens on the islands in Myvatn; *Succisa pratensis* is very numerous in Sida. A few rare plants have been found only in very far distant habitats, at opposite sides of the island, thus, *Ophioglossum vulgatum* at Gunnuhver at the extreme point of Reykjanes, and at Bjarnarflag near Myvatn. *Drosera rotundifolia* grows here and there near Breidifjörður and Faxafjörður and otherwise only in the extreme north between Eyjafjörður and Skagafjörður, *Cirsium arvense* occurs in a few localities which are as far apart as Grindavík and the Vestmannaeyjar towards the south, and Eyjafjörður towards the north.

In Iceland as in other arctic or subarctic countries with a coastal or insular climate there is comparatively but a slight difference in the vegetation of the lowlands and of the plateau, of the mountains and of the valleys; it is very difficult to arrange the species according to their altitudinal zone. Almost throughout the island, and everywhere where plant-life can thrive at all, plant-formations and plant-associations, with a few modifications, occur with a gradually increasing or decreasing luxuriance and number of species according to situation only. With the exception of the highest situated tracts, close to the snow-line, the distribution of the plants and the differences in the vegetation appear to be in a higher degree dependent on local climatic conditions, such as snow and other atmospheric precipitations, wind, conditions of soil, inclination, more or less sunny exposure, streams and springs rather than on the height above sea-level. A luxuriant vegetation with a lowland character often extends very far upwards on the mountains on the sunny side, or where a suitable degree of moisture and a protective snow-covering afford favourable conditions of life for the vegetation, while in the immediate neighbourhood, and often at a far lower level, cold sharp winds or sand-drifts have destroyed almost all plant-life and laid the land waste. Exceptionally favourable localities are afforded for plants in some places near hot springs

on the plateau. Some plant-formations such as birch-coppices and heather-moors, do not, however, extend to the highest levels, and many species disappear on approaching the snow-line; on the other hand, others, as mentioned above, are distributed in great abundance all over the island, from the sea-level to the snow-line.

The Icelandic climate affords good conditions of life for mosses, therefore Iceland has a luxuriant moss-vegetation which is not only shown in the great extent of the *Grimmia*-heaths, but proofs of it are seen in various other ways in nature. On the interior plateau in the most barren localities small green oases are often seen, consisting exclusively of mosses; on the abrupt faces of rocks they form bright green cushions around springs; and at the numerous waterfalls of Iceland there is a luxuriant moss-vegetation, rich in forms; blocks of rock and steep rock-faces are often covered with mosses, as also the numerous cracks in the lava-streams; and the damp rock-clefts are often rich in different species. Under various conditions of nature, various species of mosses are the dominant ones, and form various characteristic societies.

A considerable number of lowland species have an upper limit on mountains and plateau, but this has not as yet been thoroughly investigated. On the other hand, very few highland plants have a lower limit; the majority of the plants which grow near the snow-line thrive just as well in the neighbourhood of the sea. In many districts, and in some places on the northern peninsulas towards the North Atlantic, plant-associations with well-marked plateau-characters are seen in the vicinity of the sea; this is especially the case with associations of *Salix herbacea*, *Sibbaldia procumbens* and *Gnaphalium supinum*, which are otherwise peculiar to the plateaus. Of the commonly distributed species probably very few occur exclusively on the plateau; of such plants only *Ranunculus glacialis* is known; it grows in many localities near the snow-line and has doubtless only rarely been found below 300 metres. *Pedicularis flammea* has a similar distribution, but in some places it grows perhaps further downwards. Otherwise there are only a few rarer species which have been found only on mountains and plateau, but it is possible that on a closer investigation these may also be found at a lower level. Of these may be mentioned *Carex pedata*, *Poa laxa*, *Catabrosa algida*, *Sagina nivalis*, *Draba alpina*, *Ranunculus pygmaeus*, *Diapensia lapponica*, *Campanula uniflora*, *Antennaria alpina* and *Erigeron uniflorus*. Of common plateau-plants which also occur in



the lowlands may be mentioned, *Carex rostrata*, *C. lagopina*, *C. saxatilis*, *C. rigida*, *Eriophorum polystachyum*, *Luzula arcuata*, *Salix herbacea*, *Alsine biflora*, *Papaver nudicaule*, *Draba nivalis*, *Arabis alpina*, *A. petræa*, *Saxifraga caespitosa*, *S. oppositifolia*, *S. nivalis*, *Epilobium anagallidifolium*, *Gentiana nivalis*, *Sibbaldia procumbens*, *Gnaphalium Norvegicum*, *G. supinum*, and others. As already mentioned, many of the most common plateau-species are distributed on rocky flats throughout the country, both at high and at low levels; for instance, *Silene maritima* is as common along the coast as at the highest levels in the interior wastes, as also *Polygonum viviparum*, *Cerastium alpinum*, *Armeria maritima*, *Draba alpina*, *Oxyria digyna*, and several others. Therefore, speaking generally, it is not easy to distinguish the species of the rocky flats of the plateau from those of the lowland. The main difference consists especially in the more scattered growth of the individual plants and their partially stunted appearance on the plateau; moreover, in the lowlands several species are found intermixed with the above, often abundantly, which rarely appear on the plateau, for example, *Dryas octopetala*. Further, where the situation is favourable, very luxuriant patches may occur on the rocky flat of the plateau, at any rate in the centre of the island below 600—700 metres. As we have already seen, the altitude of the snow-line differs greatly in different districts, consequently, the characteristics of the plateau vegetation are met with at different altitudes in different parts of the island. In central Iceland the plateau-character often does not begin until at 600—800 metres, but on the northern peninsulas and headlands the plateau-vegetation often descends to an altitude of 300 metres, and in some places even lower. On the lower-lying parts of the plateau, especially in the neighbourhood of large glaciers, from which the melting snow and ice has not sufficient outlets, there are often found groups of lakes and extensive stretches of boggy and swampy land with a luxuriant vegetation of mosses and sedges. Such swampy tracts are found among other places on Tvidægra (450 metres), in the neighbourhood of Grimstungaheidi (500 metres), Miklumyrar near Hreppar (400—500 metres), Eyjabakkar near Snæfell (650 metres), Fljótsdalsheidi (400—500 metres), and several other places. The vegetation of these plateau-bogs is as yet very little known.

All the highest mountain summits and plateaus are covered with snow and ice, but along the edge of the plateau and in a few places upon the plateau itself there are several rather high mountain tops



which are snowless during summer. On these wind-blown rock-summits the plants generally encounter very unfavourable conditions, therefore many of the summits are quite bare of vegetation; on others a few lichen-crusts are seen on stones, or small *Grimmia*-cushions in clefts; and again on others a few scattered phanerogams are found. So far as is known, there are almost no notes regarding the plants on the mountain summits of Iceland, as the latter are rarely ascended by botanists, but geologists, on the other hand, are obliged to climb the mountains. I shall therefore take the opportunity here of inserting some fragmentary notes from my diary regarding the plants I found on the mountain-summits, with the heights measured. These notes were not intended for publication; I had put them down in my diary for my own information, but although they are fragmentary, they may be useful in showing that there is nothing specially characteristic in the vegetation of the mountain-summits. On the north-western peninsula: Kikafell near Brjámslækur (560 metres), *Grimmias*, *Salix herbacea*, *S. phylicifolia*, *Arabis petræa*, *Armeria maritima*, *Ranunculus glacialis*, *Silene acaulis*, all in flower July 22, 1886. Vattarfjall (401 metres), *Papaver nudicaule*, *Silene acaulis*, *Armeria maritima*. Bæjarfell near Steingrímsfjörð (316 metres), *Silene acaulis*, *Armeria maritima*, *Cerastium alpinum*, *Polygonum viviparum*, *Empetrum nigrum*, *Saxifraga cæspitosa*. Drangaháls (315 metres), *Salix herbacea*, *Polygonum viviparum*, *Oxyria digyna*, *Rhodiola rosea*. Dalsheidi near Snæfjallaströnd (660 metres), mosses, *Silene acaulis*, *Salix herbacea*, *Gnaphalium supinum*, *Sibbaldia procumbens*. Klofningsheidi (606 metres), *Grimmias*, *Salix herbacea*, *Ranunculus glacialis*, *R. pygmeus*. Uxaskard near Látrar (Eyjafjörð) (518 metres), *Oxyria digyna*, *Salix herbacea*, *Armeria maritima*, *Ranunculus glacialis*. Hafursey near Myrdalsjökull (587 metres), *Grimmias*, *Salix herbacea*, *Silene acaulis*, *Polygonum viviparum*. Lodmundur (1097 metres), NE. of Hekla, *Grimmias*, lichens, *Salix herbacea*, *Silene acaulis*, *Cerastium alpinum*, *Saxifraga cæspitosa*, *Carex rigida*. Skálafell near Ölfus (578 metres), *Salix herbacea*, *Cassiope hypnoides*, *Armeria maritima*, *Arabis petræa*. On the plateau towards the west: Thristapafell near Eiríksjökull (714 metres), *Salix glauca*, *Armeria maritima*, *Cerastium alpinum*, *Silene acaulis*, *Salix herbacea*. Strútur (921 metres), on the summit no plants, but 130 metres further downwards, *Arabis alpina*, *A. petræa*, *Saxifraga hirculus*, *S. hypnoides*, *S. oppositifolia*, *Pedicularis flammea*. Botnssulur (1108 metres), only some lichens and *Grimmias* and *Salix herbacea* and

*Empetrum nigrum* — a miserable stunted specimen of each of these two species, 2 and 2½ cm. in height respectively. On the plateau towards the east: Kjarrdalsheidi near Lón (665 metres), *Salix herbacea*, *Polygonum viviparum*, *Oxyria digyna*, *Ranunculus glacialis*, all small and stunted. Markalda (961 metres) near the eastern edge of Vatnajökull, *Polygonum viviparum*, *Armeria maritima*, *Salix herbacea*, *Saxifraga nivalis*. Litla Snæfell (1133 metres), *Salix herbacea*, *Oxyria digyna*, *Arabis alpina*, *Ranunculus glacialis*. On Hlidarfjall near Myvatn (790 metres) where I was together with Grönlund in 1876, we noted the following plants: — *Alsine biflora*, *Draba nivalis*, *Saxifraga cernua*, *Cassiope hypnoides*, *Pedicularis flammea*, *Oxyria digyna*<sup>1</sup>.

All that is situated outside the glacier-bearing mountains in the centre of Iceland at an altitude of 650—1100 metres may justly be regarded as a desert; seen both from a geological and geographical point of view the country here is desert-like in character, and in spite of considerable precipitation the plants suffer from drought, because the water disappears immediately over large areas owing to the porous nature of the rocky substratum — lava, tuff, volcanic gravel and sand. The few plants which grow in these wastes occur widely scattered; at a height of 900—1000 metres above sea-level a few lichens and mosses are seen only here and there, and at long intervals a few specimens of the hardy *Armeria maritima*, *Silene maritima* and *Polygonum viviparum* and in places where blown sand occurs a few tufts of *Elymus arenarius*; at a height of 1000—1100 metres one may ride for miles without coming across a single phanerogam. In addition to want of water, the frequent storms, often of sand and snow, check plant-growth during the short summer; moreover, a rather dry Föhn wind often blows across the wastes north of the great Jökulls, having already deposited its moisture upon the great plateaus of the Jökulls. Somewhat lower down, at an altitude of 700—900 metres, a few more species are met with as scattered individuals, e. g. *Silene acaulis*, *Arabis alpina* and *A. petraea*, and here and there a few haulms of *Luzula arcuata*, *Poa glauca* or *Festuca ovina*; moreover, a few scattered cushions or tufts of lichens (*Stereocaulon*) or mosses (*Grimmia*) occur.

Scattered here and there in these extensive wastes are sometimes

<sup>1</sup> See also Chr. Grönlund's list of plants from Heljardalsheidi and Hrafninnuhryggur, and the list of plants collected by Johnstrup on Dyngjufjöll (Karakteristik af Plantevæksten paa Island, 1884, pp. 28 and 29).

found, at intervals of a whole day's journey, some small oases with a denser vegetation, in places where water is present, especially springs which issue from under the edge of the lava-streams. I propose to give here the names of some of these oases and their height above sea-level, and add some notes on their vegetation, which is generally very little known. As almost no notes are published on the vegetation of the plateau I shall avail myself of this opportunity to give a list of the species I collected on some of these oases, as they have never been visited by botanists. Some of these plant-covered patches are only a few square metres in extent, and the largest of them are perhaps as much as a square km. in area<sup>1</sup>. These oases often originate around hot springs, the temperature of which need not be very high — somewhat higher, however, than the mean temperature of the locality at which they rise. Thus NW. of Vatnajökull there are oases near Gæsavötn, 929 metres above sea-level, where the springs have a temperature of 5—7° C., and near Marteinsflæda (744 metres) with spring-temperature of 35½° C. and near Hitalaug (672 metres) with a temperature of 33½° C. Gæsavötn is the most highly situated of all the oases that I visited in 1884; plant-growth occurs here in connection with pools and springs; along the margins the vegetation is formed by mosses and *Salix herbacea* with scattered specimens of *Polygonum viviparum*, *Saxifraga stellaris*, *Oxyria digyna*, *Armeria maritima*, *Cerastium* and *Poa*, while *Carices* and *Eriophorum* form a fringe along the water's edge. Here I collected the following plants: — *Equisetum arvense* var. *alpestre*, *Calamagrostis stricta* var. *borealis*, *Aira alpina*, *Poa pratensis*, *P. pratensis* var. *alpigena*, *Poa alpina* var. *vivipara*, *Carex in-curva*, *Eriophorum Scheuchzeri*, *E. angustifolium*, *Salix phylicifolia*, *S. herbacea*, *Polygonum viviparum*, *Oxyria digyna* f. *pygmæa*, *Armeria sibirica*, *Saxifraga stellaris* f. *pygmæa*, *S. decipiens* var. *grönlandica*, *Ranunculus hyperboreus*, *Cerastium arcticum*, *C. trigynum*<sup>2</sup>. From here I went to Hvannalindir near Kverkfjöll, the nearest oasis towards the east, but it took nevertheless two days (17, 18 Aug.) to reach it, travelling along the northern edge of Vatnajökull; along the whole of this stretch of land there were almost no plants, until at Jökulsá, 734 metres above sea-level, I found in the gravel a fairly large quantity of *Chamænerium latifolium* and *Oxyria digyna*.

<sup>1</sup> In my work "Island, Grundriss d. Geographie u. Geologie", 1906, there is a map showing the desert-boundaries and the oases known.

<sup>2</sup> Determined by Prof. Joh. Lange.

In Hvannalindir (656 metres) there occur along small streams a great many grasses and an abundance of tall specimens of *Archangelica officinalis*, but unfortunately I was prevented by a snow-storm from collecting plants there. At Vadalda at the springs of Svartá (674 metres) were found *Archangelica officinalis* and *Juncus balticus*. At Herdubreidarlindir (471 metres), north of the lofty mountain of Herdubreid, a rather rich vegetation occurs as a border along springs and branching streams while the surroundings consist of gravel quite bare of plant-life. Here I collected the following plants<sup>1</sup>: — *Equisetum variegatum*, *Phleum alpinum*, *Calamagrostis stricta* var. *borealis*, *Festuca rubra* var. *hirsuta*, *Eriophorum Scheuchzeri*, *Juncus arcticus*, *J. triglumis*, *Luzula multiflora*, *Tofieldia borealis*, *Platanthera hyperborea* var. *major*, *Salix phylicifolia* var. *angustifolia*, *S. lanata*, *S. herbacea*, *Achillea millefolium*, *Erigeron uniflorus*, *Hieracium murorum*, *Galium verum* var. *aspera*, *Thymus serpyllum* var. *prostratus*, *Bartsia alpina*, *Pirola minor*, *Archangelica officinalis*, *Parnassia palustris*, *Cerastium vulgatum*, *Silene maritima*, *Epilobium alsinifolium*, *Chamænerium latifolium*, and *Alchimilla alpina*. On Odádahraun itself there are otherwise only extremely small plant-covered patches. In Hrútsrandir near Kollóttá Dyngja (653 metres), there occurred on a bottom of *Salix herbacea* a few small individuals of *Polygonum viviparum* and *Salix glauca* and far out on a neighbouring lava-stream a single specimen of *Taraxacum officinale* — the only one for miles round. Along some mountain-streams in the south-eastern corner of Dyngjufljöll small patches of a similar vegetation were found, only *Salix glauca* was far more vigorous here. Otherwise no continuous oases are found in the higher parts of Odádahraun, but only a few very widely separated desert plants, and in some places *Elymus arenarius* on blown sand. Towards Bárdardalur the vegetation increases gradually, and the sandy tracts, as far upwards as 500 metres above sea-level, are covered with *Elymus arenarius*, *Salix lanata* and *S. glauca*, and further downwards till about 450 metres, *Achillea millefolium* grows in abundance on the sand. In Miklimór between Sudurárbotnar and Alftakill (about 450 metres) there is a considerable vegetation of different kinds of plants and even around Svartárvatn (409 metres) there is a rather rich vegetation like that on the sandy tracts of the lowlands.

On the north-eastern part of Vatnajökull east of Jökulsá and close to the glaciers, oases occur — separated by stretches of stony

<sup>1</sup> Determined by Prof. Joh. Lange.



deserts — which are as yet very little known, e. g. Thorláksmyrar, Mariutungur and Eyjabakkar (672 metres). I visited the last locality in 1894 and found there extensive areas covered with Cyperaceæ, cotton-grass and other plant-growth. In Fjallasveit, east of Jökulsá, a parish situated up on the plateau at an altitude of 400—500 metres, the population of which is solely dependent on sheep-rearing for their sustenance, very large tracts are covered with blown sand which in many places is densely overgrown with *Elymus arenarius*, *Salix lanata*, *S. glauca* and *Juncus balticus*, while *Carex incurva* grows abundantly on damp sandy flats. Near the farmstead Vidirhóll (415 metres) I collected in 1895 the following plants: — *Juncus balticus*, *J. triglumis*, *J. trifidus*, *Elyna Bellardi*, *Carex incurva*, *C. capitata*, *C. capillaris*, *C. vulgaris*, *C. rigida*, *C. rariflora*, *Poa pratensis*, *P. annua*, *Phleum alpinum*, *Festuca rubra* var. *arenaria*, *Calamagrostis stricta*, *Trisetum subspicatum*, *Selaginella spinulosa*, *Salix lanata*, *S. glauca*, *Saxifraga aizoides*, *Gentiana tenella*, *Pleurogyne rotata*.

North of Hofsjökull, at an altitude of 600—800 metres, similar barren wastes occur, as around Odádahraun, consisting of ice-striated doleritic lava, and here also the individual plants occur widely separated, but, in the neighbourhood of stream and lakes, the oases are larger both in number and size. The vegetation of these oases is generally confined to small swamps and pools and sometimes to rather extensive mountain-bogs; in the pool-vegetation *Eriophorum* is usually dominant, but sometimes *Carices* are in the majority. In mountain bogs numerous large knolls (dys) often occur which are usually dry at the top and covered with mosses and various rocky-flat plants, but wet below and overgrown with swamp-plants. Dry tracts between the swamps are generally covered with *Grimmia*-heaths which sometimes pass into lichen-heaths. Of the oases occurring in these districts may be mentioned: Sydri Pollar, Nyrðri Pollar, Geldingaá and Laugafell (with hot springs), and southwards near Sprengisandur, on the eastern side there is Nyidalur, and on the western side Nauthagi and Arnarfell with an unusually luxuriant vegetation which has been described by St. Stefánsson<sup>1</sup>, who also describes the plant-formations near Laugafell and Geldingaá. In Nyrðri Pollar (704 metres) I collected in 1896 the following plants: *Poa alpina*, *P. flexuosa*, *Carex rigida*, *Eriophorum angustifolium*, *Salix lanata*, *S. glauca*, *S. herbacea*, *Pedicularis flammea*, *Tofieldia*

<sup>1</sup> Geografisk Tidsskrift, XVI, 1902, pp. 230 and 231.



*borealis*, *Alsine biflora*, *Cerastium trigynum*, *Saxifraga Hirculus*<sup>1</sup>. In Sydri Pollar (729 metres) I collected in the same year the following plants: — *Equisetum variegatum*, *E. arvense*, *Carex rigida*, *C. lagopina*, *C. rariflora*, *C. pulla*, *Juncus arcticus*, *J. biglumis*, *Eriophorum Scheuchzeri*, *E. angustifolium*, *Poa alpina*, *P. flexuosa*, *Phleum alpinum*, *Aira alpina*, *Festuca rubra* var. *arenaria*, *Calamagrostis stricta* f. *borealis*, *Salix glauca*, *S. lanata*, *S. herbacea*, *S. phylicifolia*, *Betula nana*, *Polygonum viviparum*, *Rumex acetosa*, *Arenaria ciliata*, *Cerastium alpinum*, *Silene acaulis*, *Cardamine pratensis*, *Tofieldia borealis*, *Montia rivularis*, *Thalictrum alpinum*, *Pinguicula vulgaris*, *Armeria maritima*, *Saxifraga decipiens*, *S. Hirculus*, *Pedicularis flammea*, *Eriogon uniflorus*, *Thymus serpyllum* var. *prostrata*, *Veronica alpina*, *Dryas octopetala*, *Vaccinium uliginosum*, *Empetrum nigrum*, *Bartsia alpina*<sup>2</sup>. As already mentioned, on Tvidægra there are extensive stretches of bog-land and a considerable vegetation of various species. In 1898 I collected here, near Ulfsvatn (453 metres), the following plants: — *Juncus biglumis*, *J. triglumis*, *J. trifidus*, *Luzula spicata*, *Eriophorum angustifolium*, *E. Scheuchzeri*, *Carex alpina*, *C. atrata*, *C. dioeca*, *C. lagopina*, *C. pulla*, *C. rigida*, *C. sparsiflora*, *Aira cæspitosa*, *A. flexuosa*, *Anthoxanthum odoratum*, *Festuca ovina*, *F. rubra*, *Phleum alpinum*, *Poa alpina*, *P. glauca*, *Trisetum subspicatum*, *Coeloglossum viride*, *Salix glauca*, *S. herbacea*, *Polygonum viviparum*, *Alsine verna*, *Cerastium alpinum*, *C. trigynum*, *Silene acaulis*, *Viscaria alpina*, *Ranunculus acer*, *Thalictrum alpinum*, *Cardamine pratensis*, *Draba incana*, *Geranium silvaticum*, *Saxifraga cæspitosa*, *S. Hirculus*, *S. stellaris*, *Potentilla verna*, *Alchimilla vulgaris* f. *filicaulis*, *Sibbaldia probens*, *Vaccinium uliginosum*, *Bartsia alpina*, *Pinguicula vulgaris*, *Thymus serpyllum* var. *prostrata*, *Gentiana nivalis*, *G. tenella*, *Galium silvestre*, *Hieracium alpinum*, *Taraxacum lævigatum*. In the same year I collected near Hvalvatn (378 metres) the following species: — *Juncus triglumis*, *J. trifidus*, *Eriophorum angustifolium*, *Carex chordorrhiza*, *C. dioeca*, *C. Goodenoughii*, *C. lagopina*, *C. pulla*, *C. rariflora*, *C. rigida*, *Aira cæspitosa*, *A. flexuosa*, *Anthoxanthum odoratum*, *Festuca ovina*, *Phleum alpinum*, *Poa glauca*, *Tofieldia borealis*, *Loiseleuria procumbens*.

South of the great Jökulls the vegetation generally extends further upwards on the plateau than to the north of them, but here also there are vast deserts of gravel, lava and blown sand, with a few widely separated oases, but it is especially the tracts between

<sup>1</sup> Determined by O. Gelert.

<sup>2</sup> Determined by O. Gelert.

Thjórsá, Skaftá and Mýrdalsjökull which are desert-like in character, and here there are also several bare tuff-ridges with numerous peaks. The sand is constantly drifting through the valleys and destroying all vegetation; only upon the highest ridges and peaks, which cannot be reached by the coarser grains of the drifting sand are seen several yellowish-green patches of mosses, and also along streams and around springs the moss-vegetation is sometimes fairly luxuriant and forms rather large green patches in places where very few or no phanerogams have been able to gain a foothold. Around Tjaldvatn (588 metres) in Veidivötn there is a considerable vegetation of different species; in 1889 I collected here the following plants: *Carex rigida*, *Poa pratensis*, *Festuca ovina*, *Salix glauca*, *Montia rivularis*, *Ranunculus acer*, *Batrachium paucistamineum*, *Thalictrum alpinum*, *Koenigia islandica*, *Empetrum nigrum*, *Rhodiola rosea*, *Parnassia palustris*, *Chamænerium latifolium*, *Hippuris vulgaris*, *Euphrasia latifolia*. Near Thorisvatn (591 metres) which is situated in the centre of large sandy deserts quite bare of vegetation, I found only *Salix glauca*, *Chamænerium latifolium* and *Carex rariflora*. On Blesamyri (535 metres) near Tindfjallajökull I found *Carex rigida* and *C. rariflora*. Near Hitalaug (650 metres) east of Torfajökull, in the neighbourhood of hot springs I found *Coeloglossum viride*, *Saxifraga stellaris*, *Sibbaldia procumbens*, *Pirola minor*, *Vaccinium uliginosum*, *Veronica alpina*, *Gnaphalium Norvegicum*, *G. supinum*, *Hieracium alpinum*. Near Hvannabotnar (434 metres) in the neighbourhood of Skaftá I collected: — *Equisetum palustre*, *Luzula campestris*, *Carex rigida*, *Calamagrostis stricta* f. *borealis*, *Anthoxanthum odoratum*, *Sibbaldia procumbens*, *Epilobium lactiflorum*, *E. Hornemanni*, *Gnaphalium Norvegicum*. Though the above list is naturally very incomplete owing to the author having had other work in hand (geographical survey and geological investigations) which left him no time for thorough botanical investigations or collections, yet these notes have been included here as these parts of the plateau are very difficult of access and are hardly ever visited by naturalists.

Outside the deserts in central Iceland, and nearer to the sea, there are also many, large and small, high-situated rocky areas and broken groups of rocks, pieces of plateau, and isolated peaks in the numerous mountain-spurs which extend between the branching valleys and fjords. The vegetation of these rocks is also very little known, but it resembles very much that of the plateau, only, it is usually richer in species. Highest up on the mountains, at an alti-

tude of 600—800 metres, there are usually gravelly tracts with scattered individuals of rocky-flat plants, such as *Silene acaulis*, *S. maritima*, *Cerastium alpinum*, *Luzula arcuata*, *Polygonum viviparum*, *Armeria maritima*, *Ranunculus glacialis*, *Saxifraga nivalis*, *S. oppositifolia* and others. In small damp hollows where the snow persists for a long time there is often a characteristic dense growth of *Salix herbacea*, which almost entirely conceals the moss-covering of the ground, together with *Sibbaldia procumbens*, *Gnaphalium supinum*, *Oxyria digyna* and *Polygonum viviparum*; in some places these are associated with several other plants. In other places there are small patches of Grimmia-heaths with scattered specimens of *Pedicularis flammea* or *Cassiope hypnoides*. Here and there streams and bogs occur with *Carex rigida*, *C. lagopina*, *C. rostrata*, *C. incurva* and others, but most often with *Eriophorum angustifolium* and *E. Scheuchzeri*.

As has been seen from the preceding notes on the vegetation of the plateau it is not easy to determine the altitudes or upper limits of the different plant-regions. Of the Scandinavian upper zones, the region of conifers is entirely absent, but, on the other hand, we may be justified in speaking of a birch-region, of an osier-willow region, and perhaps a lichen- or moss-region, but these regions pass into one another in many ways, and overlap. During the period after the Ice Age (the *Purpura-lapillus* Period) when it was warmer than it is now, the birch grew everywhere in the lowlands even on the northernmost headlands, but it had already retired from the latter at the time the first settlers came to the island, and since then, as we have already seen, its distribution has been considerably limited owing to the interference of man and sheep. The present Polar limit of *Betula odorata* in Iceland has not been fully investigated, but judging from what I saw on my journeys it appears, on the east coast, to extend across Vopnafjörður to the west coast of Melrakkasletta, across Axarfjörður and Skjálfandi to Eyjafjörður near the mouth of the valley of Fnjóskadalur. The stretch of land between Eyjafjörður and Hunaflói is now devoid of birch coppices, although these occurred there in olden times; how far out they extended at that time upon the peninsulas between the fjords is not known. From Hunaflói the northern limit of the birch extends from Steingrímsfjörður to Isafjardardjúp. This is, however, only quite a provisional limit; the subject requires to be investigated more closely. As regards the upper limit of the birch, it differs considerably in different parts of the island; it extends highest in Thingeyjarsýsla

— near Myvatn to 550 metres. Birch coppices occur on the mountains of Vindbelgur (540 metres) and Dalfjall (550 metres). In olden times there were in Króksdalur and Yxnadalur — a continuation of Bárdardalur — considerable woods up to 450 metres. On the south coast the birch coppices do not as a rule extend so far upwards on the mountains; in Kollumuli near Lón birch coppices oc-



Fig. 27. Woods in Hallormstad; June 1909.

(Phot. A. Hesselbo.)

cur, however, at a height of about 500 metres, but, nowhere else along the south coast did I find birch coppices at that altitude. The forest of Nupsstadaskogur, south of Vatnajökull, reaches to an altitude of 400 metres, Bæjarstadaskógur in Øræfi to 320 metres, and coppices in Haukadalsheidi to 380 metres, but in the southern lowlands the limit for birch coppices usually occurs at a height of 200—300 metres; in some places at a slightly higher, in others at a slightly lower level. According to the Ordnance map the upper limits of the coppice-woods in South Iceland are as follows: —

Skaftafell in Øræfi .....	280 metres
Jökulfell (Bæjarstadaskogur).....	320 —
Nupsstadaskogur .....	400 —
Thorsmörk .....	320 —



Markhlidar . . . . .	250	metres
Burfell near Thjórsárdal . . . . .	300	—
Skridufellsskogur . . . . .	220	—
Tungufellsskogur . . . . .	260	—
Haukadalsheidi . . . . .	380	—
Uthlidarhraun . . . . .	320	—
Laugardalsskogur . . . . .	280	—
Thingvallaskogar . . . . .	200	—
Botnsskogur . . . . .	200	—
Skorradalur . . . . .	150	—
Svinadalur . . . . .	200	—
Husafellsskogur . . . . .	260	—
Hvitársida . . . . .	300	—

Although it is possible that birch coppices may be met with in some places at a somewhat higher level yet the limits will be approximately those given above. On the north-western peninsula, birch coppices occur mostly on the southern side at the head of the valleys and fjords which extend upwards from Breidifjörður and face the sun; but the birch coppices extend hardly anywhere higher than 200—300 metres, and usually occur at far lower levels. There is also a good deal of birch coppice at the branch-fjords of Arnarfjord, in Dyrafjord and at the southern fjords of Isafjardardjup, especially at Hestfjörður. North of Isafjardardjup I nowhere saw birch coppices proper, although a few individuals of *Betula odorata* occur in some places in Adalvik; nor are birch coppices known to occur on the east coast from Cape Nord to Steingrimsfjord.

To the birch region belongs also *Sorbus aucuparia* which occurs as scattered individuals both in the birch coppices and outside them; I do not think the mountain ash extends so far up as does the birch; I did not observe it at higher altitudes than on Sluttnes in Myvatn, 290 metres above sea-level. *Betula nana* occurs now and then in birch woods, but grows most commonly on heather moors and in bog-lands; it rarely forms coppices proper. It extends higher on the mountains than *Betula odorata*; I found it, for instance, in Sydri Pollar, 729 metres above sea-level. *Juniperus communis* is fairly common in birch coppices and on heather moors; the highest altitude at which I found it was in Yxnadalur near Odádahraun, 488 metres above sea-level. The heather moor is closely associated



with the birch region, and it probably rarely extends higher than 300—400 metres above sea-level as an aggregate plant-formation; but several of the different species of which the heather-moor is composed extend far higher up on the mountains without forming any heath-like associations, occurring as a few individuals only. I found *Vaccinium uliginosum* at the highest level (729 metres) near Sydri Pollar, and also *Dryas octopetala* at the same place; *Empetrum nigrum* extends to a similar height, and I came across a stunted specimen even on the top of Botnssulur at an altitude of 1108 metres. *Cassiope hypnoides* extends to a great height also; it is found, among other places, on Hlidarfjall at 790 metres above sea-level, and may perhaps extend even higher. *Loiseleuria procumbens*, on the other hand, did not occur at a higher level than 400—500 metres. *Calluna vulgaris*, *Arctostaphylus uva ursi* and *Vaccinium Myrtillus* were found near Myvatn at an altitude of about 400 metres, but I do not think they extend higher than the limits of the heather moor.

Above the upper limit of the birch region an osier or a willow region may be said to occur — in the centre of the country at an altitude of 500—800 metres, in other places somewhat lower — where willows are dominant among the woody plants, although they have their greatest distribution at a far lower level, in the birch region itself. At this altitude they do not form any coppice proper, but occur as flat expanses of low prostrate shrubs. Above the birch region it is especially *Salix herbacea*, *S. lanata* and *S. glauca* which are the dominants; *Salix phylicifolia* retires, although small specimens of the latter also are now and then met with even at this altitude. *Salix lanata*, and to some extent *S. glauca*, occupy large areas of the lower parts of the plateau, e. g. in Fjallasveit, Myvatn-söræfi, Sudurárbotnar, and several other places; they are of great importance to sheep-breeding, and in some places quantities of willow leaves are gathered as winter-fodder for sheep and cattle; in the lowest part of this zone *Betula nana* occurs now and then. In the centre of the country above 800—900 metres and up to the snow-line at an altitude of 1000—1400 metres, mosses and lichens are undoubtedly the dominant plants, although a few widely scattered phanerogams also occur. *Salix herbacea* extends also through this region to the snow-line; here and there, the most hardy of the previously mentioned rocky-flat plants occur as somewhat scattered individuals, but the main vegetation consists of mosses, although these do not occur in any great abundance compared with the vast

areas. Mosses often form an edging or fringe around loose stones on gravelly flats or also cushions on heaps of stones or in rock-crevices. On the highest situated and most inhospitable rocky and gravelly tracts, where storms are constantly driving sand and gravel across the surface, not even mosses can thrive, and the ground is quite bare. A few species of lichens (*Cladonia* and *Cetraria*) are sometimes found in the moss cushions, but usually they occur only as crusts on blocks of rock. Here and there on clayey soil in depressions crusts of liverworts occur, especially *Anthelia nivalis*, often associated with *Grimmia hypnoides* and *Salix herbacea*; round pools and along streams, cushions of bright green mosses are often seen, in which some flowering plants have sometimes found a home. In other parts of the country, the three regions mentioned here occur at a lower level, since they are correlated with the altitude of the snow-line in the different parts of the country.

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## V. A SKETCH OF THE CHIEF PLANT-FORMATIONS OF ICELAND.

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WE will now give a brief account of the commonest and, from a geographical point of view, most important plant-formations of the land-vegetation of Iceland, without, however, entering into details or into local deviations of the different plant-associations. This account is based partly on my own observations and partly on those published by others; I have especially made use of Dr. Helgi Jónsson's numerous excellent descriptions of the vegetation-forms of Iceland. Here I shall confine myself to the purely geographical distribution without entering more closely into relations of causation, or into questions of general ecology, which will no doubt be exhaustively discussed later on. The division into plant-formations and -associations is as yet, in many respects, dependent upon individual opinion. In the following, with the exception of a few deviations, I am adopting Dr. H. Jónsson's main divisions. Dr. Jónsson is the most experienced investigator of the vegetation of Iceland, and has described the plant-life from many more parts of Iceland than has anyone else. But much work remains to be done by future investigators; the vegetation-conditions from more than one-half the total area of the island are still to be described, and so many local variations, and such varied associations occur within the larger formations that it will be a long time before the details from everywhere are well-known. The following is only a brief account for the general orientation of the larger plant-formations and of the chief points regarding the distribution of the higher plants according to present knowledge<sup>1</sup>.

<sup>1</sup> Besides the above-mentioned works on the flora of Iceland, there are the following descriptions of the vegetation: — Chr. Grönlund: *Karakteristik af Plantevæxten paa Island, sammenlignet med Floraen i flere andre Lande* (Naturhistorisk Forenings Festskrift, 1890 [printed 1884], pp. 107—145). C. H. Ostenfeld: *Skildringer af Vegetationen paa Island* (Botanisk Tidsskrift, XXII, 1899, pp. 227—

The Vegetation of the Coast-line. The halophilous plant-associations along the greatly extended coast-line of Iceland have, as in other places, a rather heterogeneous soil consisting of fine and coarse strand sand, large pebbles or boulders, blown sand and rocks of basalt and tuff. Very generally round the coast there is seen upon low rocks<sup>1</sup>, at the foot, a belt of *Verrucaria maura*; then come grey, yellow and green patches of several kinds of lichens; above this level only a few plants occur, mostly scattered individuals of *Cochlearia officinalis*, *Plantago maritima*, *Armeria maritima* and *Glyceria distans*. On steep, lofty coast-cliffs *Cochlearia officinalis* and *Rhodiola rosea* often occur in great abundance, also *Silene maritima*, *Armeria maritima*, *Cerastium alpinum* and various species of *Poa* and *Festuca*; to these should be added *Haloscias scoticum* in south-western Iceland and especially on the islands in Breidifjörður. As is well-known, there are several large sea-fowl cliffs along the coast of Iceland, but their vegetation has not yet been investigated; H. Jónsson has investigated only a few smaller sea-fowl cliffs in Dalasyssel and "sea-fowl-grass-slopes" (Fuglegræslier) in Skaftafellssyssel. According to H. Jónsson (1905, p. 37) the grass-covered mountain-slopes in South Iceland frequented by sea-fowl differ from the common grass-slopes, among other things in the abundant occurrence of *Poa pratensis* and *Stellaria media*; the occurrence of *Festuca elatior* and *Avena elatior* on "sea-fowl-grass-slopes" is also characteristic of the latter. The vegetation of the lofty sea-fowl cliffs appears principally to consist of the same plants as are found on common coast-cliffs, for instance, *Cochlearia*, *Rhodiola*, *Archangelica*, as also *Oxyria* and *Stellaria*; all growing luxuriantly. Owing to the soil being manured there is an immigration of many other species, especially from the grass-slope and the grassland; these species grow as luxuriantly in rock crevices and on ledges as in the most well-manured home-fields. Collections of plants from these sea-fowl cliffs have never been made; the plants being extremely difficult of access.

253; XXVII, 1905, pp. 111—122). Th. Thoroddsen: Planteverdenen paa Island (Salmonsens Leksikon, IX, 1899, pp. 606—607). Helgi Jónsson: Studier over Ost-Islands Vegetation (Bot. Tidsskr., XX, pp. 77—89). Vegetationen paa Snæfellsnes (Vidensk. Medd. fra naturh. Foren. i København, 1900, pp. 15—97). Vegetationen i Syd-Island (Bot. Tidsskr., XXVII, 1905, pp. 1—82). Vegetationen paa Island (Atlanten, 1904, pp. 41—50). Gróðrar- og Jarðvegrannsóknir (Búnaðarrit XX, 1906, pp. 146—181; XXIII, 1909, pp. 41—54). Fyrirlestur um gróður Islands (Búnaðarrit, XXI, 1907, pp. 6—20). Bygging og lif plantna, København, 1907, pp. 289—300.

<sup>1</sup> Cf. Eug. Warming: Dansk Plantevækst, I, København, 1906.

On the strand sand, especially in South Iceland, there is a fairly characteristic vegetation of *Halianthus peploides*, *Cakile maritima*, *Atriplex patula*, *Stenhammaria maritima* and *Potentilla anserina*; often, each of these species occurs separately and in abundance, but sometimes they are found intermixed in various ways. *Cakile maritima* usually occurs nearest to the sea, and *Potentilla anserina* at the highest levels, occupying large areas, and occurring so abundantly that the ground is quite interwoven by its creeping shoots. On the strand sand are also seen in small numbers *Cochlearia officinalis*, *Matricaria inodora*, *Silene maritima*, *Polygonum aviculare*, *Stellaria crassifolia*, *S. media*, *Capsella bursa pastoris*, *Glyceria distans*, *Festuca rubra*, *Elymus arenarius*, *Carex incurva*, etc. On the vast sandy stretches along the south coast blown-sand formations are frequent nearest to the sea; here *Halianthus peploides* and *Elymus arenarius* occur in tufts; above this belt of sand dunes, tracts are found occupied by a vegetation richer in species and consisting of *Potentilla anserina*, *Festuca rubra* var. *arenaria*, *Thymus serpyllum*, *Galium verum*, *Achillea millefolium*, *Juncus balticus*, and several others. But below the glacier-bearing mountains (Jökulls) the strand sand quickly merges into glacier sand, which forms sandy wastes extremely poor in plant-life.

At several places along the coast of Iceland salt-marshes are found, overflowed by salt water, for example in Borgarfjörður, Myrar, Hornafjörður and Lón. In Myrar the dominant species are *Glyceria maritima*, *Agrostis alba*, *Plantago maritima*, *Stellaria crassifolia*, moreover *Heleocharis uniglumis*, *Triglochin maritima*, *Juncus bufonius*, several species of *Carex*, etc. H. Jónsson found that in some places two-thirds of the area was occupied by *Glyceria maritima* and one-third by *Agrostis alba*, each species occurred separately in patches; some thick-leaved *Plantago maritima* occurred, however, in the *Glyceria patches*<sup>1</sup>.

**The Vegetation of the Fresh Water.** Plant-life occurs very sparingly in running water, and where strong currents are felt it is usually absent. Nor do plants appear to thrive in glacier-rivers; this is probably due to the low temperature of the water and the current. In slowly flowing river-arms on level land, in rivulets and brooks there is often a considerable quantity of green algæ (*Zygnema* and *Spirogyra*), both at the bottom and upon the surface; in South Iceland *Enteromorpha intestinalis* is common in streams. The fol-

<sup>1</sup> Bunadarrit, XX, 1906, pp. 150, 151.



lowing mosses are found on stones in rivulets and brooks: *Fontinalis antipyretica* very frequently, also *F. gracilis* and *F. thulensis*, *Amblystegium Kneiffii*, *A. ochraceum*, *Hypnum rusciforme* var. *atlantica*, and others<sup>1</sup>. The vegetation of lakes and pools is much richer and differs considerably according to the depth of the water and the nature of the bottom, etc. The plankton of the Icelandic lakes has as yet been very little investigated; there are only a few notes to hand from Myvatn and Thingvallavatn. In Myvatn zooplankton only was found; Thingvallavatn contained phytoplankton in which diatoms were dominant<sup>2</sup>. In deep lakes there is usually very little or no vegetation at greater depths, only in places where it is shallower does plant-life occur. In Thingvallavatn, however, there are large areas covered with *Chara* and *Nitella*, especially at a depth of 13—30 metres, and they extend even down to 38 metres<sup>3</sup>. Where the lakes are shallower various species of *Potamogeton* and *Myriophyllum* and also *Batrachium paucistamineum* are common. Near the margin and in smaller pools the most common, and usually dominant, species are the following: *Heleocharis palustris*, *Equisetum limosum*, *Carex rostrata*, *Menyanthes trifoliata*, and in the southern lowlands *Glyceria fluitans* is common; to these should be added *Hippuris vulgaris*, *Eriophorum angustifolium*, *Sparganium minimum*, *S. submuticum*, *Ranunculus hyperboreus* and *R. reptans*, *Subularia aquatica*, *Callitriche hamulata* and *C. verna*, *Limosella aquatica* and several others, the occurrence of which varies somewhat according to the quantity of the water, the conditions at the bottom, etc. Where *Equisetum limosum* occurs in abundance it is cut annually and used for fodder for milch cows. In Myvatn and in other lakes in Thingeyjarsýsla *Nostoc*-lumps are found in abundance, often thrown up on the shore in very great quantities. Sometimes in warm summers large areas of Myvatn become turbid; this phenomenon is known by the inhabitants as "leirlos" — it is said to be very injurious to salmon-trout, their gills becoming filled with the fine particles — when this occurs they retreat in great numbers to the eastern shore of the lake, where the water is purer and clearer owing to the numerous springs which here issue from the lava<sup>4</sup>.

<sup>1</sup> H. Jónsson, 1900, p. 17, 1905, p. 7.

<sup>2</sup> C. H. Ostenfeld and C. Wesenberg-Lund: A Regular Fortnightly Exploration of the Plankton of the two Icelandic Lakes, Thingvallavatn and Myvatn. Proc. R. Society Edinburgh, Vol. 25, Part 12, 1906, pp. 1092—1167).

<sup>3</sup> B. Sæmundsson in Andvari, 1904, p. 89.

<sup>4</sup> Dr. H. Jónsson informs me that the so-called "leirlos" is probably due to Blue-green Algæ perhaps *Aphanizomenon flos aquæ*.

Springs (kaldavermsl, dy<sup>1</sup>) are very common in Iceland, and are found in almost every valley below the mountain-sides or appear in rows upon the ledges of the basalt-layers. The peculiar vegetation connected with these streams is widely distributed below the mountain-sides and often occurs in the midst of other formations or high up on the mountain-sides in narrow zones in places where other vegetation is wanting. This vegetation is characterized especially by the fresh bright-green colour of the mosses; *Philonotis fontana* is everywhere the dominant plant, but many other species of moss also occur, especially *Pohlia albicans* var. *glacialis*, and various species of *Bryum*, *Amblystegium*, and several other genera. Several phanerogams occur among the mosses, the most common are *Epilobium alsinifolium*, *E. Hornemanni*, *Cerastium trigynum*, *Montia rivularis*, *Saxifraga stellaris*, and *Catabrosa aquatica*, sometimes associated with *Ranunculus hyperboreus* and *Caltha palustris*, *Marchantia polymorpha*, etc. As this spring-vegetation usually occurs close to bogs and swampy tracts, there are often transitions to bog- and swamp-vegetation.

Vegetation around Hot Springs. Peculiar to Iceland is the characteristic vegetation near hot springs. The heat of the soil and the hot water create exceptionally favourable conditions for plant-life, so that species which otherwise do not grow in Iceland can thrive here, and species from South Iceland which do not otherwise grow in North Iceland also occur here near hot springs. It is to be regretted that the vegetation connected with these springs has been more closely investigated in a few places only<sup>2</sup>. It is especially the rich algal flora, which for instance is of great importance as regards the separation of silica from the hot water, which requires investigation. The vegetation around the hot alkaline springs is usually very luxuriant and may extend over fairly large areas, because the aqueous vapour floats above the surroundings and descends as a continuous, drizzling rain of tepid water. The plant-associations may differ somewhat according to local conditions, as to whether the surroundings are damp or dry, gravelly or rich in humus. Where the surroundings of the springs consists of a hard grass-bottom, the following

<sup>1</sup> In Iceland the word "dy" is also applied to small pools in swampy tracts.

<sup>2</sup> Plant-life near the hot springs has been investigated especially by C. Ostfeld, Bot. Tidsskr., vol. 22, 1899, pp. 299—245; by Chr. Grönlund: Karakteristik af Plantevæxten paa Island, pp. 33—35 and by Japetus Steenstrup and F. M. Liebmann, Forhandl. v. d. skandin. Naturforskeres 2. Møde 1840, København, 1841, pp. 336—340.

plants are common: *Potentilla anserina*, *Leontodon autumnalis*, *Trifolium repens*, *Brunella vulgaris*, *Gnaphalium uliginosum* and *G. silvaticum*, *Hydrocotyle vulgaris*, *Ranunculus acer*, *Sagina procumbens*, *Spergula arvensis*, *Plantago major*, *P. maritima* f. *pygmæa*, *Polygonum persicaria*, *P. aviculare* and various Gramineæ, and sometimes *Vicia cracca*. Where it is damper occur *Epilobium palustre*, *E. alsinifolium*, *Cardamine multicaulis*, *Montia rivularis*, *Limosella aquatica*, *Juncus lamprocarpus*, *J. bufonius* and some *Carices*. The composition of these groups of species differs however considerably at the different kinds of springs. Of vascular plants the following have been observed exclusively near alkaline hot springs: *Hydrocotyle vulgare*, *Gnaphalium uliginosum*, *Veronica anagallis*, *Polygonum persicaria*; rare outside the range of influence of hot springs are *Galeopsis tetrahit*, *Plantago lanceolata*, *P. major* and *Blechnum spicant*. Moreover, C. Ostenfeld enumerates eight species of mosses which have been found only on warm soil, and three species which are especially connected with a warm ground. In North Iceland some species grow only near hot springs, which in South Iceland thrive also outside the area of the warm soil, for instance, *Brunella vulgaris*, *Plantago lanceolata*, *Cardamine multicaulis* and *Drosera rotundifolia*. In the outlets from both the warm and hot springs an abundance of algæ often occurs — often in a great heat — which have not as yet been investigated. Near solfataras vegetation is extremely sparse, and in the immediate neighbourhood of the sulphurous-acid fumaroles no plant-life can thrive, therefore only bare clayey flats occur there. *Ophioglossum vulgatum* grows only near solfataras; in 1882 I found at Bjarnarflag near Myvatn scattered, but numerous, specimens of it on clayey ground which had a temperature of 27°C. — it occurred together with *Sagina procumbens* and *Poa pratensis*; and in 1883 I found it near Gunnuhver on Reykjanes also on warm clay in the neighbourhood of sulphur springs. In both localities it occurred together with the otherwise rare *Riccia bifurca* and *Chomocarpon commutatus*. C. Ostenfeld found it on Reykjanes in the neighbourhood of steaming holes, “first a crust was found held together by a *Stigonema*-species, then a great many Muscineæ of which the most characteristic were *Riccia bifurca* and *Chomocarpon commutatus*. Amongst them occurred some other mosses: *Pohlia nutans* v. *filicaulis*, *Fossombronia Dumortieri*, *Bryum ventricosum*, *Fissidens osmundioides* and *Philonotis fontana*, moreover, the characteristic *Ophioglossum vulgatum* var. *polyphylla*” (loc. cit. p. 240).

Ostenfeld also describes the vegetation near the boiling mud-pools, and writes: "Close to the mud-pools the ground is quite bare, and not until some distance from them do plants begin to appear; nearest to them occurred *Agrostis alba* forming a net-work with its long rhizomes, and beyond this came a dense, low carpet of *Sagina procumbens*, *Cerastium vulgatum*, *Plantago major* (dwarf-form), *Stellaria media* and a great abundance of *Grimmia hypnoides*; somewhat further off many other plants occurred." "The vegetation near the outlet of the large mud-pool Gunna was characteristic and peculiar; here the damp ground (about 30° C.) was covered by a pure, green carpet of *Nardia crenulata* in which only one other plant occurred, viz. *Juncus bufonius*; within there was firm soil the particles of which were held together by moss-protonema. The moss-carpet became brownish-red where the ground was drier, but it was only *Nardia* which changed colour; some mosses occurred, however, along the outer edge . . . . ., but only as a subordinate component" (loc. cit. pp. 239, 240). Near numerous solfataras in the neighbourhood of Myvatn, on Odádahraun, Kerlingarfjöll, Torfajökull, and in several other places no vestige of plant-life occurs.

Vegetation on Wet Soil (bogs, pools, swamps and wet meadows). Bog- and swamp-land (myrar) is very extensively distributed in Iceland, both on the plateau and in the lowlands and valleys; these tracts are also of great economic importance, as in the inhabited districts the grass is cut for hay, and the hay (útthey) is used as winter-fodder for sheep and ponies. In Iceland the swampy meadow-tracts are divided according to their water-content into two main divisions, myri (pl. myrar) and flói (pl. flóar); the soil of the former is firm and tough owing to the interwoven roots and rhizomes; in the latter the soil is rotten, and more loosely connected, so that cattle thrust their legs through it and easily get stuck fast; in the former the surface is saturated with the ground water, but in the latter the water reaches to the surface or slightly above it, consequently here pools of all sizes abound. Upon the flat surface of the "myrar" small cone-shaped knolls usually occur, and in "flóar" water-channels and swampy holes are often found between the knolls. The vegetation is far denser and more continuous in the former than in the latter. The dominant species in the swampy "flói" are *Carex chordorrhiza*, *Eriophorum angustifolium* and *Scirpus cæspitosus*, and frequently occurring species are *Carex rostrata*, *C. saxatilis*, *C. Goodenoughii*, *C. limosa*, *C. rariflora* and several other *Carices*, as also



*Menyanthes trifoliata*, *Equisetum limosum*, *Heleocharis palustris*, etc. Upon the knolls, which are dry, many other plants occur, often *Betula nana*, *Vaccinium uliginosum*, *Salix glauca*, etc. The ground-vegetation consists of several species of mosses, *Amblystegium*, *Sphagnum*, *Hylocomium*, and others. On the mountains *Eriophorum*-bogs are very frequent and *Carex*-bogs of rarer occurrence, but in the lowlands the reverse is the case. Moss bogs with different aquatic



Fig. 28. Geitabergsvatn. Flooded meadow with *Eriophorum* and *Carex*.  
(Phot. A. Hesselbo.)

vegetation, as at the above-mentioned springs, often occur in these swampy tracts, and pools with *Equisetum limosum*, *Hippuris vulgaris*, *Menyanthes* and *Sparganium*. The Icelandic "myrar" are richer in species and have a denser vegetation than the "flóar." The dominant plants are *Carex cryptocarpa* and *C. Goodenoughii*, but in addition many other species of *Carex* occur, viz. *C. rariflora*, *C. canescens*, *C. microglochin* and others, moreover, *Eriophorum Scheuchzeri*, *Equisetum palustre*, *Comarum palustre*, which are characteristic of wet meadows, *Caltha palustris*, *Parnassia palustris*, *Cardamine pratensis*, etc. Almost everywhere the above-mentioned genera and many others are associated with a moss-bottom. Sometimes some *Gramineæ*, *Polygonum viviparum*, *Euphrasia officinalis*, etc. occur upon the knolls, and in south-west Iceland, here and there on moss-covered knolls, *Drosera rotundifolia*. From the outer edge of the



water-saturated tracts, where the ground is becoming drier, are easy transitions to other plant-formations, such as grassland, heather-moor, etc.

Rocky flats. Of all plant-formations, the rocky-flat-formation occupies the largest area in Iceland, and is the one which characterizes by far the greatest part of the island. In favourably situated localities nearest the coast it passes into a "herb-flat" (Urtemark) with



Fig. 29. Lake near Armuli. with *Carex rostrata*.  
(Phot. A. Hesselbo.)

a dense vegetation of different plants, and with some mosses and lichens; but usually the plants are too scattered to have any influence worth mentioning upon the appearance of the landscape. The vegetation of the rocky flat, which includes a great proportion of all the plant-species of the island, may be divided into many sections according to soil-conditions. On climbing higher up on the plateau we find that species and individuals become fewer in number and more scattered in growth, and as already stated, in the highest parts of the plateau only a few stunted, widely separated plants occur. On rocky flats situated at high levels mosses play an important part, especially *Grimmia hypnoides*, which gradually forms soil for higher plants; now and then some fruticose lichens are found intermixed with the mosses, and in many places on the

plateau patches of *Anthelia nivalis* occur. The rocky-flat-formation appears to be an original, late Glacial formation from which a great many distinct formations have developed, the different species having become associated according to their conditions of life. The outer limits of the rocky flat are the *Grimmia*-heath and the "herb-flat," but transitional stages to heather-moor and grassland often occur. As sub-divisions or nearly related formations the following may be mentioned: — gravelly flats (melar), stone-covered ridges (holt); fallen blocks and debris upon mountain slopes (urd, pl. urdir), steep cliffs (hamrar), gravelly river-plains and river-terraces (eyrar), sandy tracts of various kinds, clayey flats and lava-streams.

Gravelly flats (melar) also occupy large areas in the lowlands: the soil-conditions differ somewhat, but generally the gravel is mixed with clay and then the surface often cracks into polygonal cakes and forms a "rudemark" (p. 257). These "rudemarks" greatly influence plant-distribution, as the plants generally resort to the gravel bands between the cakes, where they find shelter and protection. Sometimes gravelly flats are so poor in plant-life that they appear quite bare and naked; sometimes they are so densely covered as almost to form a "herb-flat." The most common plants on gravelly flats in the lowlands are *Cerastium alpinum*, *Arabis petræa*, *Draba hirta*, *Silene acaulis*, *S. maritima*, *Armeria maritima*, *Salix herbacea*, *Sagina nodosa*, *Spergula arvensis*, *Arenaria ciliata*, *Alsine verna*, *Thymus serpyllum*, *Dryas octopetala*, *Papaver nudicaule*, *Oxyria digyna*, *Rumex acetosella*, *Trisetum subspicatum*, *Poa glauca*, *Festuca ovina*, *Agrostis alba*, *Luzula multiflora*, *L. spicata*, etc. Naturally all the above-mentioned species do not occur together; in some places a great many of them may occur, while in other places a very few, perhaps only three or four, may be found. The vegetation is also somewhat dependent upon neighbouring plant-formations. Usually mosses or lichens are very sparsely present upon these gravelly flats in the lowlands; only here and there small *Grimmia*-cushions occur.

On stone-covered ridges (holt) there is usually a greater variety as regards soil and situation than on the gravelly flats, and the vegetation there is sometimes fairly luxuriant and conspicuous especially in early summer when *Silene acaulis*, *Dryas octopetala* and *Thymus serpyllum* are in bloom; these are very common there, and also the majority of the plants of gravelly flats. Moreover, the following are noteworthy: *Alchimilla alpina*, *Saxifraga cæspitosa* and *S. oppositifolia*, *Viscaria alpina*, *Empetrum nigrum*, *Sedum acre*

and *S. annuum*. As the environment of the ridges differs greatly — sometimes bogs, sometimes dry grassland, sometimes heather — the vegetation on the ridges also differs somewhat in the different districts owing to immigration from these plant-associations. Mosses



Fig. 30. *Dryas octopetala* (Vallanes; June 26, 1909).  
(Phot. A. Hesselbo.)

are few in number, but there is often an abundance of crustaceous lichens, chiefly various species of *Lecideas* and *Lecanoras*, which often impart a strongly variegated appearance to the rocky boulders.

River gravel has one characteristic plant all throughout Iceland, viz. *Chamaenerium latifolium*, the splendid, purple flowers of which occur in large patches upon gravel-tongues between branching rivers, and can be seen from a distance. Besides plants common to gravelly flats several willows often occur here, viz. *Salix glauca*, *S. lanata* and *S. phylicifolia*, and also *Saxifragaceæ*, *Galium verum*, *G. silvestris*, and others. Clayey flats with a denser vegetation and a soil rich in humus frequently occur at the outer edges of gravelly



flats; they have a characteristic vegetation consisting of *Koenigia islandica*, *Sedum villosum*, *Juncus alpinus*, *J. biglumis* and *J. triglumis*; moreover, *Epilobium palustre*, *Spergula arvensis*, *Sagina procumbens*, *S. nodosa*, *Stellaria crassifolia*, *Polygonum aviculare*, *Equisetum palustre*, *Triglochin palustris*, *Agrostis alba*, *Luzula spicata* and some other species occur frequently, which are distributed according to the water content, etc. of the clayey flats.

The vegetation of mountain-slopes is often only an extension of that of the rocky flats, with the difference that greater variations occur at the base of the mountains, the conditions there being more highly diversified: the stony tracts alternating with bogs, springs, grass-slopes, heather-moors, coppice-woods, etc. But frequently mountain slopes consists mainly of downward-gliding gravel-masses or angular rock-fragments, with little or no vegetation, the stone-covering being too unstable to permit plants to gain foothold; in other places are heaps of loose blocks of rock (urd) or solid rock-terraces or -faces; in many places mountain-streams excavate channels or deep ravines, and at the base of mountains they cause the formation of broad gravel-cones with branching streamlets with mosses and other plants connected with springs, or with transitions to bog-formations. On the rock terraces there is sometimes a soil-layer which, according to the conditions of moisture, supports either Gramineæ or Cyperaceæ. Therefore, on mountain-slopes, many different plant-formations are found in patches close to one another in many transitional stages. In the rock-detritus on mountain slopes which are not too steep, plants common on rocky flats occur, but none that are really characteristic: the following have been noted: *Silene acaulis*, *S. maritima*, *Alchimilla alpina*, *Dryas octopetala*, *Thymus serpyllum*, *Cerastium alpinum*, *Armeria maritima*, *Saxifraga cæspitosa*, *S. hypnoides*, *S. stellaris*, *Potentilla maculata*, *P. anserina*, *Sedum acre*, *Erigeron alpinus*, *Veronica saxatilis*, *Poa glauca*, *P. alpina*, and several others. Nor are there many characteristic plants in the vegetation of the rock-faces. Tuff and breccia mountains are generally richer in plants than basalt mountains, their surfaces having many more crevices and hollows in which plants can gain foothold. The following plants occur on steep mountain-sides: *Archangelica officinalis*, *Rhodiola rosea*, *Haloscias scoticum*, *Polypodium vulgare* and *Woodsia ilvensis*, also *Cochlearia officinalis*, especially on sea-fowl cliffs; *Saxifraga Cotyledon* grows only on rocks in south-eastern Iceland. Moreover, in rock-clefts various ferns occur, most frequently *Cystopteris*

*fragilis*, but also flowering plants, such as *Sedum annuum*, *Oxyria digyna*, *Plantago maritima*, *Saxifraga caespitosa*, *Poa glauca*, *Festuca ovina*, and others. On damp rock-faces near large waterfalls these same species are met with, often as large, well-developed specimens (H. Jonsson, 1905, p. 30); also *Poa alpina* f. *vivipara*, *Aira alpina*, *Saxifraga hypnoides*, *S. stellaris*, *S. nivalis*, *S. caespitosa* and several



Fig. 31. The river Thverá in Öxnadal. *Epilobium latifolium* and *Aira* on a small gravel-island in the river: July, 1909.  
(Phot. A. Hesselbo.)

species of mosses. Nowhere is seen so mixed and variegated a plant-society as on extensive, fairly densely plant-covered mountain slopes where the majority of the plant-formations are met with, in patches, side by side. On a talus of fallen blocks and débris (urd) there is often a considerable vegetation of lichens, mosses and liverworts. In some places, especially far up on the mountains, the sloping heaps of rock-fragments are poor in plants: in other places they carry a rich vegetation of ferns or willows and birch shrubs and heather, with a variable admixture of herbaceous plants from different formations, with no special character, the vegetation resembling closely that which occurs in ravines and lava-clefts.

Where the conditions of life are specially favourable; where the



situation is suited to plant-life with southern exposure, an adequate supply of water, shelter from sharp winds, and intense sunlight during spring a "herb-slope" (Urteli<sup>1</sup>) or "herb-flat" (Urtemark) is formed which on the one hand passes gradually into a rocky-flat formation, and on the other into a birch coppice; it chiefly contains the plants of these two formations, but the growth is dense and luxuriant, so that the ground often appears to be entirely covered by the closely-placed plants. Dicotyledonous flowering plants are the most important, grasses are absent or of subordinate importance. The soil consists of clay or gravel mixed with humus, upon which mosses sometimes occur. Such herb-slopes are found in patches on mountain-sides, on basalt-terraces or on the inclines below rocks, in large ravines and in sheltered, sunny hollows; they often form beautiful carpets, in which the various species usually occur intermixed with each other. As a rule, the dominant species are *Geranium silvaticum*, *Spiræa ulmaria*, *Archangelica officinalis*, *Angelica silvestris*, *Geum rivale*, *Bartschia alpina*, *Alchimilla vulgaris*, *Brunella vulgaris*, *Rubus saxatilis*, *Vicia cracca*, *Myosotis arvensis*, *Leontodon autumnalis*, several species of *Hieracium*, *Rumex acetosa*, *Ranunculus acer*, *Poa*, *Agrostis* and *Aira*; intermixed with these occur several other species, but less frequently. In some parts of the island other characteristic species are frequently noted in "herb-slopes," for instance in East Iceland, *Campanula rotundifolia* and *Saxifraga aizoides*, and in some places in South Iceland *Valeriana officinalis* and *Lychnis flos cuculi*.

Sand-covered tracts (sandar). As already mentioned, sandy tracts occupy vast areas — several thousand kilometres surface — in Iceland, both in the lowlands and on the plateau. The physical conditions of these "sandar" differ somewhat, therefore their vegetation, although usually homogeneous and poor in species, may now and then vary somewhat in details. The vast sandy wastes below the glacier-bearing mountains (Jökulls) of South Iceland are mainly formed of glacio-fluvial gravel and sand, but also partly of volcanic ashes and scoriæ, while there are wide stretches upon which both the fine and the coarse gravel is mixed with clay. Sometimes extensive stretches are occupied by alternating clayey flats and pebble-covered river-beds; there are also tracts strewn with ice-striated boulders, and extensive areas, especially on the plateau, covered

<sup>1</sup> Urteli (herb-slope) and Græsli (grass-slope; see p. 335) denote plant-covered slopes where dicotyledonous flowering plants and grasses are dominant respectively.

with blown sand. Where the sand-covered tracts reach the shore their outermost border supports a halophilous vegetation which, at a short distance from the coast, is replaced by the common plants of sandy soil and rocky flats. On gravelly tracts of sand in the low-lands the following plants are the commonest: *Silene maritima*, *Armeria maritima*, *Festuca rubra*, v. *arenaria*, *Carex incurva*, *Agrostis alba*, *Juncus balticus*, *Elymus arenarius* and *Potentilla anserina*; also *Galium verum* and *Thymus serpyllum*, often occurring in patches. Although the vast stretches of glacial sand in South Iceland have a fairly variable surface yet they are extremely poor in plant-life; owing to "glacier-bursts," and to glacier-rivers constantly causing floods and changing their courses, the vegetation has rarely the chance of development. On Skeidarársandur (cf. H. Jónsson, 1905, pp. 20—22) the following plants occur widely scattered: *Chamænerium latifolium*, *Arabis petræa*, *Silene maritima*, *Saxifraga oppositifolia*, *S. cæspitosa* and *Poa glauca*, also small patches of *Grimmia hypnoides*; but there are, in addition, large stretches quite naked and entirely destitute of plant-life. The main part of Myrdalsandur is a desert almost devoid of vegetation; far apart occur a few specimens of *Arabis petræa*, *Silene maritima* and *Elymus arenarius*; usually there is no vestige of plant-life, and one may ride for hours without seeing a single plant. In a few localities in Breidamerkursandur and Skeidarársandur there is open grass-vegetation in small oases where the sandy gravel from some cause or another has for some length of time escaped inundation by the ice-cold glacier water; in such places, in addition to *Chamænerium latifolium* there occurs usually *Agrostis alba*, *Poa alpina*, *P. glauca*, *Aira alpina*, *Calamagrostis stricta*, *Festuca ovina*, *F. rubra* v. *arenaria*, *Carex incurva*, *Juncus balticus*, *J. triglumis*, *Luzula spicata*, *Salix lanata*, *Oxyria digyna* and others. As may be seen, there is nothing specially characteristic in the vegetation of these tracts of glacial sand and if they were rescued from the destructive effect of the glacier-rivers, they would quickly become covered by the various plant-formations of the level country: we have already mentioned one such instance, when Brunasandur in 1783 was rescued from the inundations of glacier-rivers by a lava-stream, which pushed a large river aside.

Blown sand supports a somewhat more peculiar flora, the characteristic plant being *Elymus arenarius*; but where it is very mobile, as e. g. on the plateau in the neighbourhood of Fiskivötn and between Tungná and Skaftá, no plant-life can thrive on it.

Where the sand becomes more stable, or there is shelter, *Elymus arenarius* appears, often associated with *Festuca rubra* v. *arenaria*; not until the sand becomes somewhat fixed do other species appear, e. g. *Juncus ballicus*, *Carex incurva*, *Agrostis alba*, *Festuca ovina*, *Silene maritima*, *Salix lanata*, *S. glauca* and occasionally *Halianthus peploides* in localities not too far away from the coast. Extensive



Fig. 32. *Salix lanata* and. in the background, *Betula odorata* growing in black blown-sand (volcanic ash) near Jökulsá, between 'As and Svinadal; July, 1909.

(Phot. A. Hesselbo.)

tracts are covered with different *Salices*, especially in Fjallasveit, where in some places on sandy flats *Carex incurva* also occurs in abundance; moreover, in Myvatnsöræfi, Sudurárbotnar, Rangárvellir, and several other places. Where the soil is broken up and removed by sand-storms as deep down as to the underlying gravel, as in several places in the southern lowlands in the neighbourhood of Hekla, small tufts of *Festuca rubra* and *F. ovina* are the first to appear, then come *Juncus ballicus*, *Equisetum arvense*, *Agrostis alba*, *Silene maritima*, *Salix lanata* and *S. glauca*; then gradually several species of grasses make their appearance until at last a grassy willow-flat is formed which makes an excellent sheep pasture. Here and there on the plateau are damp flats of old blown-sand inter-

sected with clefts, rent by frost, which are filled with *Grimmias* and *Salix herbacea*.

The flora of the lava-streams cannot be referred to any single plant-formation, because according to the age and the progressive development of the vegetation, the lava may bear on it all possible kinds of plant-formations. Nevertheless in Iceland several plants



Fig. 33. Lava-field in Nordrárdal in the district of Borgarfjörð (Aug. 3, 1909). The lava is covered to a depth of one foot with a layer of *Grimmia hypnoides*. Projecting parts of the lava are covered with crustaceous lichens. Here and there a tuft of *Festuca ovina*. Birch coppice in the background.

(Phot. A. Hesselbo.)

are more particularly associated with lava-streams and have there found shelter in the numerous clefts and depressions, where conditions of life are especially suitable for them. *Paris quadrifolia* is found only on lava-streams, and also ferns are found, in abundance and often as very large specimens. *Aspidium filix mas*, *A. spinulosum*, *A. lonchitis* and *A. phegopteris* very rarely occur in other habitats than lava-clefts; *Athyrium filix femina*, *Woodsia ilvensis*, *Polypodium vulgare*, *Aspidium dryopteris* and *Cystopteris fragilis* are also common in lava-clefts, although they are also met with fairly often in other localities, between blocks of rock and in rock-clefts. *Milium effusum* occurs also most frequently in lava-clefts. On lava-



streams there is a good opportunity of studying the development of the different plant-formations and plant-societies because, at the beginning, every lava-stream is virgin soil, where plant-life must break entirely new ground. The first establishment of vegetation is due to mosses and lichens; on the 23-years-old Krakatindshraun Dr. H. Jónsson found twelve species of mosses, three of lichens and one alga. Two of the lichen-species, *Stereocaulon alpinum* and *Squamaria gelida*, were widely distributed on lava-domes, the mosses usually occurred in clefts, but nowhere had a moss-carpet yet developed (H. Jónsson, 1905, pp. 55—56). The next stage is the *Grimmia*-heath, which occurs as a continuous covering over the low-lying parts of the lava, while crustaceous lichens form crusts upon the protruding points; the *Grimmias* form the soil-layer which is primarily necessary for the growth of higher plants. In this moss-foundation occur several lichens and scattered specimens of flowering plants from different associations. After this the development on the lava-streams in the lowlands proceeds in various directions according to the surface-conditions of the lava, the nature of the rock and other circumstances, such as the greater or less amount of drifted sand or humus which has settled upon the surface, and whether a supply of water is available, etc. Consequently, in the course of time a lava-stream may support either a heather-moor, a coppice-wood, a "herb-flat", or grassland, or all these plant-formations may be simultaneously present on the same lava-stream. Rocky-flat formations proper, do not occur on lava-streams, except very rarely, when the lava-streams become covered with gravel brought down by mountain streams or glacier rivers. On the plateau the vegetation on a great many of the lava-streams does not go beyond the lichen-stage, on others a considerable number of *Grimmias* are present, but almost never as a continuous covering, such as they form in many places in the lowlands and especially on the peninsula of Reykjanes. On the other hand the lava-streams of the plateau are frequently covered with drifted sand and support a sand-vegetation which at higher levels consists of *Elymus arenarius* and at lower levels of different *Salices*. There are a few instances of old, partially blocked and sand-covered lava-streams in the valleys, in localities where water was abundantly present, forming the substratum of swampy grassland with peat. Thus, in the course of time, a lava-stream may give rise to almost any formation<sup>1</sup>.

<sup>1</sup> For further information regarding plant-life on lava-streams see H. Jóns-



The *Grimmia*-heath formation is co-ordinate with the rocky-flat formation, but is not so widely distributed by a great deal as is the latter. As already mentioned, it reaches its fullest development on the lava-streams in the lowlands, especially in the peninsula of Reykjanes, where it occupies vast areas; but it also occurs on many other lava-streams. Where there are sand-drifts *Grimmia*-carpets occur very sparsely or are entirely absent, as *Grimmia hypnoides*, the most common species, cannot thrive in drifting sand; therefore extensive areas around Hekla, Fiskivötn and several other places are practically bare of mosses. On the vast lava-fields on the plateau mosses occur very sparingly. In several places the *Grimmia*-heaths on the lava-streams of the lowlands are comparatively quickly transformed into soil for higher plants, which are fairly numerous even in the *Grimmia*-carpet; generally the latter, in the course of time, passes into heather-moor; sometimes into patches of grassland. In several places the *Grimmia*-heath covers, with its characteristic grey carpet, stony mountain-slopes, and areas strewn with rock fragments, and, as is the case with the rocky flat, forms the foundation of a scattered vegetation of many different species, without any special character, but dependent upon the plant-formations of the neighbourhood. Usually the *Grimmia*-heath develops more quickly into heather-moor or grassland than does the rocky-flat formation, owing to the abundant material for soil-formation supplied by the mosses. *Grimmia*-heaths occupy large areas in the lower part of the plateau, but very few flowering plants are found there in them; on the other hand, lichens often occur numerously, especially *Cetraria* and *Cladonia*, not however so numerously that they form a lichen-heath proper, which occurs in Iceland only in patches, and is of no great importance. In the highest parts of the interior of Iceland the *Grimmia*-heath formation is of much less importance than in the lower part of the plateau.

Grassland. Ground covered chiefly with grasses or grass-like plants may be classified under four heads: grass-slopes (Græsli); knolly grassland (Græsmo); flat uncultivated grassland; and home-fields, artificially manured soil. Grass-slopes (Græsli). The lower

son: Gróðrarsaga braunanna á Íslandi (Skirnir, 1906, pp. 150—163); Vegetation paa Snæfellsnes (Vid. Medd. Nat. Foren., 1900, pp. 81—84), and Vegetation i Syd-Island (Bot. Tidsskr., 27 Bd., 1905, pp. 53—61). C. H. Ostenfeld: Skildringer af Vegetationen paa Island (Bot. Tidsskr., 22 Bd., 1899, pp. 245—253). Chr. Grönlund: Karakteristik af Plantevæxten paa Island, pp. 30—32.

slopes of mountains are often grass-covered, especially when the rock is tuff or breccia; in South Iceland the tuff mountains are often entirely grass-covered, at least on the southern side, and sometimes they are covered with a thick layer of soil without knolls proper, which occur only on the clay ground of the lowlands. But sometimes wavy rows of small knolls, or narrow ripple-like ledges occur in the lowest part of the grass-slope, and sometimes above these, for a great distance up, the surface of the soil is undulating and wave-like; this is undoubtedly due to mud-flows in the clayey soil-covering. On basalt mountains the grass-vegetation extends upwards in tongues or occurs in patches in depressions or on ledges, separated by considerable tracts of stones and gravel. On such a grass-slope, in addition to the grasses, many other kinds of herbaceous plants are more or less numerous represented. In South Iceland, according to H. Jónsson, the following are the dominant species: *Agrostis vulgaris*, *A. canina*, *Anthoxanthum odoratum*, *Festuca ovina*, *Poa alpina*, *P. nemoralis*, *Geranium silvaticum*, *Trifolium repens*, *Brunella vulgaris* and *Leontodon autumnalis*; less common, but often occurring locally in great abundance: *Spiraea ulmaria*, *Linum catharticum*, *Rubus saxatilis*, *Gentiana campestris*, *Myosotis arvensis*, *Parnassia palustris*, and many others; in Fljotshlid *Carum carvi* is very common and in Myrdalur and Sida *Succisa pratensis*. The vegetation is rich in species and is rather mixed, although grasses preponderate. In other parts of the country where basalt is dominant the grass vegetation of the mountain-slopes consists of similar species, but is not so luxuriant as in South Iceland. The following species are common: *Agrostis vulgaris*, *A. alba*, *A. canina*, *Anthoxanthum odoratum*, *Nardus stricta*, *Aira flexuosa*, *A. caespitosa*, *Phleum pratense*, *Poa alpina*, *Hierochloa borealis*, *Festuca rubra*, etc. A special *Nardus*-association and an *Anthoxanthum*-association often occur.

Knolly grassland (Græsmo). By this is understood dry, extremely knolly stretches of clayey ground intermixed with humus, occurring on level land and in valleys with a mixed vegetation of Gramineæ, Juncaceæ and Cyperaceæ; it may therefore differ considerably in appearance, according to which of these families predominates. When grasses predominate the "Græsmo" resembles grassland, but sometimes *Juncus trifidus* and *Elyna Bellardi* are so dominant that large stretches attain a brownish tint like that of a heather-moor. Usually, the vegetation of the knolls differs from that of the depressions: in the depressions, mosses and some *Carices*

are often met with, but upon the knolls there are *Elyna Bellardi* and *Juncus trifidus*; sometimes these are intermixed with mosses and lichens. In some places *Juncus balticus* predominates, in others *Luzula* or *Agrostis*, *Aira cæspitosa*, *Trisetum subspicatum* and other grasses.

The dry uncultivated grassland without knolls (hardvelli, valllendi) usually has for a substratum coarse sand, river-gravel, pebbles, etc., with a thin covering of humus, and a low and rather open vegetation which chiefly consists of Gramineæ (*Festuca*, *Aira*, *Poa* and *Agrostis*), but these are abundantly intermixed with *Juncus balticus*, *Luzula multiflora* and *L. spicata* and *Elyna Bellardi*; *Festuca rubra* is sometimes a dominant species. Of dicotyledonous plants the following are common: *Leontodon autumnalis*, *Thalictrum alpinum*, *Draba verna*, *Galium verum*, *Euphrasia officinalis*, *Viola tricolor*, *Gentiana campestris*, *Achillea millefolium*, *Rhinanthus minor*, and others.

The home-field (tun) is the manured grassland round the farm-buildings. It is usually enclosed and generally abounds in large knolls. In 1909 the area of the home-fields throughout the island was estimated at 188 square kilometres. The hay (tada) from these home-fields is kept chiefly for winter-fodder for cows. The cultivation of the home-fields differs greatly, which again influences the vegetation, other plant-associations occurring in patches in the grass-covered area of the home-field; these are especially dependent upon the degree of moisture contained in the different parts of the field. In really well-cultivated home-fields throughout the country the vegetation is everywhere homogeneous. The Gramineæ are dominant, especially *Aira cæspitosa*, *Poa pratensis* and *Festuca rubra*; moreover *Festuca ovina*, *Poa trivialis*, *P. annua*, *Agrostis vulgaris*, *Alopecurus geniculatus* and *Anthoxanthum odoratum* are very common, and intermixed abundantly with these occur *Ranunculus acer*, *Taraxacum officinale*, *Rumex acetosa* and *Polygonum viviparum*. The home-fields are often quite yellow with *Ranunculi* (*R. acer* and *R. repens*); in many places *Trifolium repens* and *Rhinanthus minor* also occur abundantly. In some places *Viola tricolor* is abundant in home-fields, especially in Eyjafjörður, and *Geranium silvaticum* in some places in Myrdalur, and in other places *Vicia cracca*, etc. In addition, many other plants are found in patches, according to the dampness of the soil and the care given to the cultivation of the home-fields; in dry and sandy grassland there often occur an abundance of *Galium verum*, *G. silvestre*, *G. boreale*, *Achillea millefolium*, *Leontodon autumnalis*,

*Armeria maritima*, as also *Luzula*, *Elyna*, etc.; in damp home-fields are found *Caltha palustris*, *Cardamine pratensis*, *Koenigia islandica*, *Montia rivularis* and different *Carices*. Moreover, a great many species often immigrate from the plant-formations of the neighbourhood; in some places, in badly kept home-fields, even swamp vegetation and willow-coppices or heather may be met with in patches. The



Fig. 34. Outer edge of the home-field (tun) of the farmstead Hnausar in Vatnsdal. *Matricaria inodora* and *Capsella Bursa pastoris*; in the background *Rumex domesticus*: July 28, 1909. (Phot. A. Hesselbo.)

farm-buildings are, as a rule, in the centre of the home-field, and around them there is almost always a characteristic vegetation consisting of *Alopecurus geniculatus*, *Glyceria distans*, *Ranunculus repens*, *Poa annua* and *P. trivialis*; quite near to the home and stables grow *Stellaria media*, *Capsella bursa pastoris*, *Polygonum aviculare*, *Rumex domesticus*, etc. Around farmsteads in the vicinity of the sea, and on islands, are often found in addition *Cochlearia officinalis*, *Cakile maritima* and *Atriplex patula*. In Iceland the walls and roofs of peasants' houses are generally built of turf and are therefore overgrown with various grasses, especially *Glyceria distans*. Flowering plants also often occur upon houses; they vary in the different districts; in south-west Iceland *Matricaria inodora* grows luxuriantly



on the roofs and in some places *Achillea millefolium*; in various districts *Rhodiola rosea* has been planted on the walls, and in the northernmost districts *Cochlearia officinalis* often occurs in abundance upon the houses, and in some places *Saxifraga rivularis*. At their base the house-walls are green with *Prasiola crispa*; various mosses also grow upon the houses, especially *Bryum argenteum*<sup>1</sup>.

Heather moors are extensively developed in Iceland both in the lowlands and valleys, on mountain-sides and on hills to a height of about 400 metres; they are not recorded from higher levels. On mountain-sides and on hill-slopes the heather moor is almost flat, on level land it is usually knolly; it is best developed upon old lava-streams and it often forms the ground vegetation of birch coppices. The dominant species are *Empetrum nigrum*, *Vaccinium uliginosum*, *V. myrtillus*, *Arctostaphylus uva ursi* and *Calluna vulgaris*; the last species is fairly common in many districts, but never occurs so abundantly as the others. Moreover, among the heather there is usually an abundance of *Dryas octopetala*, *Juniperus communis*, *Betula nana*, *Rubus saxatilis* and *Salix herbacea*. In heathy tracts at higher levels and also above these in scattered patches, are found *Loiseleuria procumbens*, *Cassiope hypnoides* and *Sibbaldia procumbens*. On the peninsulas on either side of Eyjafjörður patches of *Phyllodoce coererulea* — which is not recorded from more southerly habitats — are now and then found. There is a great variation in the distribution of the different character-plants in the heather moor; sometimes they all occur mixed with each other; sometimes each occurs separately in large or small patches, so that the different areas may be designated *Vaccinium* heaths, *Empetrum* heaths, *Calluna* heaths, *Arctostaphylus* heaths, etc. Between the heather, as ground vegetation, other plants occur in abundance, especially immigrants from the knolly grass-land — from which the knolly heather-land often appears to have been derived — for instance, *Juncus trifidus*, *Elyna Bellardi*, *Luzula multiflora*, *L. spicata*, *Nardus stricta*, *Agrostis canina*, *A. alba* and several other Gramineæ, also *Salix lanata*, *S. glauca*, *S. phylicifolia*, *Silene acaulis*, *Thymus serpyllum*, *Bartschia alpina*, *Alchimilla alpina*, *Thalictrum*, *Galium*, *Hieracium*, and many others. In addition, there is very often a moss-carpet of *Grimmia hypnoides* beneath the heather.

Willow coppices. Although the various species of willows are widely distributed they rarely form coppices proper, and willow

<sup>1</sup> As regards the moss-vegetation on old house-walls see Helgi Jónsson's above-mentioned paper on the vegetation of South Iceland. 1905, p. 54.



coppices, as independent formations, have but a slight distribution in Iceland. As stated above, *Salix lanata* and *S. glauca* are distributed over extensive sandy areas, and occur there, together with some other plants, as dominants; in other places they occur on dry, flat, clayey tracts, as scattered shrubs of low growth (20—60 cm.) with an undergrowth of heather, *Elyna Bellardi*, various species of grasses, etc. It is chiefly *Salix phylicifolia* which forms coppices



Fig. 35. Knolly moor of *Betula nana* intermixed with *Salix lanata* and *Salix phylicifolia*  
Ground vegetation: *Empetrum*, *Arctostaphylus uva ursi*, *Anthoxanthum odoratum* and  
*Polygonum viviparum*. (Phot. A. Hesselbo.)

(e. g. near Skaftafell, Fnjóskadalur, Hrafnkelsdalur, Kaldalón and Mývatn) in association with *Salix lanata* and *Betula odorata* and with a rich ground-vegetation of highly diverse plants common on “herb-flats.” Now and then *Salix phylicifolia* forms the undergrowth of birch coppices, as for instance, in Bæjarstadaskogur near Øræfi: the willows here have an average height of 2 metres; the highest individuals are 3 metres in height, but the stems are only 18—24 cm. in circumference. *Salix phylicifolia* (often together with *Salix lanata*, which may attain a height of 1—1½ metres) is often found interspersed in birch coppices, in many places in different districts. In several places near Mývatn *Salix phylicifolia* forms coppices, among other places in Sluttnes, where a stem which I measured in 1882,

had a circumference of 21 cm. and a length of 5 metres, but it could not stand erect.

Birch coppices. An account has already been given of the distribution of birch coppices in Iceland, and in a subsequent part



Fig. 36. Hallormstadvaskógur; 1894 (see text).  
(Phot. Th. Thoroddsen.)

of this work there will no doubt be an exhaustive description of tree-distribution in Iceland, so here only a few very brief notes on the subject will be given. The greater part of the birch coppices in Iceland consists of stunted shrubs having, as a rule, a height of 1—3 metres only, sometimes even lower; a fact which is undoubtedly due to the destructive habits of sheep. Well-grown birches — the remains of woods which have formerly been far more extensive — occur, however, in a few localities. Of such woods the following

are the most important: Hallormstadaskógur near Lagarfljót in East Iceland, Bæjarstadaskógur below Jökulfell in Øræfi in South Iceland, and Thórdarstadaskógur and Hálsskógur in Fnjóskadal in North Iceland. In Hallormstadaskógur some erect birch trees have a height of 8—9 metres and a circumference of 70—80 cm., and many others have a height of 5—7 metres. In Thórdarstadaskógur the highest tree is  $8\frac{1}{2}$  metres high, with a circumference of 32 cm.; several of the trees are 6—7 metres high, and the average height of the whole wood is 3—4 metres. Hálsskógur is somewhat lower; some of the trees are, however, 6—7 metres high, and several 4—5 metres<sup>1</sup>. Bæjarstadaskógur is somewhat lower, but the trees are well-grown and erect, and stunted birches are absent; the average height of the birch trees is 4—5 metres and may often be as much as 6 metres<sup>2</sup>. In a ravine near Skaftafell I measured in 1894 a birch tree which was 7 metres high and a mountain ash which had a height of  $9\frac{1}{2}$  metres. This tree occurs sometimes dispersed in birch coppices, and sometimes separately in ravines and on mountain slopes; it has often been allowed to stand on account of some superstition. In some places in North and South Iceland the mountain ash (*Sorbus aucuparia*) has been planted around farmsteads and by houses in towns. It attains a height of 7—10 metres, but in birch coppices it is generally only 4—5 metres, or even less. In birch coppices are also found *Betula nana*, *Salix phylicifolia*, *S. lanata* and *S. glauca* and *Juniperus communis*. The soil in coppice-woods consists often of “moar” — knolly clay which rests sometimes on gravel and sometimes upon rock. Coppices often occur also on a stony bottom, as in ravines, between rocky boulders, and often upon mountain slopes — occasionally they are found on boggy soil. The wood-floor is very often occupied by heather moor; and birch coppices of lower growth often even pass into heather moor; in the latter case the same species are found in the woods as are found on ordinary heather moors, and they form similar associations<sup>3</sup>.

<sup>1</sup> S. Sigurdsson: Skógarnir í Fnjóskadal (Andvari, XXV, 1900, pp. 144—175).

<sup>2</sup> H. Jónsson, 1905, pp. 46—50. Th. Thoroddsen in Geografisk Tidsskrift, XIII, 1895, pp. 16—17.

<sup>3</sup> During latter years many papers have been written on the woods of Iceland. One of the most important is that by C. V. Prytz: Skovdyrkning paa Island in Tidsskrift for Skovvaesen, vol. XVII, 1905, pp. 20—89; it also contains interesting notes on the Icelandic soil. Moreover, works dealing with the woods of Iceland are enumerated in Lysing Islands, vol. 2, on pp. 443—445.

Sometimes the trees grow in grassland, and sometimes on "herb-flats;" occasionally the wood-floor consists of mosses. In grassland the commonest species are *Agrostis vulgaris*, *Aira flexuosa* and *Anthoxanthum odoratum* and other more scattered Gramineæ. Where the herb-flat formation is dominant many different species occur, especially *Spiræa ulmaria*, *Angelica silvestris*, *Rubus saxatilis*, *Leonodon autumnalis*, *Geranium silvaticum*, *Bartschia alpina*, *Myosotis arvensis*, *Alchimilla vulgaris*, *Fragaria vesca*, and others. *Trientalis europæa* grows here and there in woods in East Iceland only. Where mosses are dominant on the wood-floor the vegetation consists chiefly of *Hylocomium* (H. Jónsson, 1900, p. 76). On the whole, in coppices, scattered individuals of the numerous species from the different formations in the neighbourhood may be found.

















